(Not for Publication)

RESULTS OF CODLING MOTH INVESTIGATIONS, 1934

Part II

Work Conducted by the Fruit Insect Division,
Bureau of Entomology and Plant Quarantine,
U. S. Department of Agriculture.

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REPORT ON CODLING MOTH INVESTIGATIONS

FRUIT INSECT DIVISION - 1934

Bureau of Entomology and Plant Quarantine,
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I. WORK UNDER PUBLIC WORKS ADMINISTRATION FUNDS.

In recognition of the urgent need for an early solution of the problem of spray residue, particularly on apples, pears, and grapes, the Public Works Administration granted on allotment of funds to the Department of Agriculture in the spring of 1934 for a special investigation looking toward a solution of this problem. Of the total grant, the sum of $103,215 was allotted to the Bureau of Entomology and Plant Quarantine. To quote the language of the grant, this was "for the investigational work needed on nonpoisonous sprays, bait traps, parasites and other methods of control which will lead to the elimination of poisonous sprays now used on apples, pears, grapes and other important fruit crops."

With this allotment it was decided to carry on extensive field testing of numerous organic materials, together with intensive laboratory work intended to develop new materials for subsequent testing. In addition, the scope of the investigation was broadened to include experiments with light traps and materially to strengthen the work under way with bait traps, orchard sanitation and biological control.

The funds became definitely available on April 10, at which time the apple trees in many northwestern orchards were approaching full bloom. The late start was naturally a serious handicap to the work, but this was gradually overcome as the season progressed.

Although most of the work was carried on apart from the work of the regular stations of the Division, much of it was supervised by field leaders of the regular staff. The Insecticide Division (Transferred to the Bureau of Entomology and Plant Quarantine September 1, 1934) participated actively in the insecticide investigations at certain of the field stations. Special mention should be made of the services rendered by Dr. R. H. Robinson of the Insecticide Division (on leave from the Oregon Agricultural Experiment Station) who visited most of the field experiments and made many helpful suggestions.

Most of the work was carried on in cooperation with various State organizations. In several cases they permitted the temporary employment of members of their staff, and furnished quarters and other facilities, without which the organization of the work so late in the season would have been much more difficult, if not impossible.

1. Large-scale Field Experiments with Organic Insecticides.

The materials tested included nicotine, derris, cube, pyrethrum, and phenothiazine. The nicotine was tested in combination with oil; in the form

of nicotine tennate, a mixture of free nicotine and certain mixtures of tannins referred to by the trade as tannic acid; and as a factory-prepared nicotine-bentonite mixture which had shown considerable promise. The derris and cube were used in the form of very finely ground root, one part of which was mixed with three parts of a finely divided kaolin, the final mixture to contain approximately 1 percent of rotenone. The pyrethrum was similarly prepared and contained approximately 0.25 percent of pyrethrins. Phenothiazine was suggested by the Insecticide Division. Laboratory tests in the late spring were sufficiently favorable to warrant taking the material into the field as far as the available supply permitted. In each series of experiments, the standard of comparison was lead arsenate, applied in accordance with locally prevailing schedules and without oil or other sticker.

In order to obtain as conclusive information as possible during a single season, the tests were conducted in three different regions, under widely different climatic conditions. Tests in the East were located at Kearneysville, W. Va.; those in the Middle West at St. Joseph, Mo., and those in the Northwest at Parma, Idaho, and Hood River and Talent, Oregon. At the last-named place the experiments were on pear; at the other points mentioned they were on apple. At Sandusky, Ohio, tests were conducted on grapes for the control of the grape berry moth.

In interpreting the results of the experiments, it should be borne in mind that the better treatments were placed at a serious disadvantage by being tested in plats adjacent to plats treated with material which proved to be quite ineffective. Since the greater proportion of the materials tested failed to give control, there was undoubtedly extensive migration during the summer from the poorly protected trees into those treated with better materials. This means that those treatments giving the best results, such as lead arsenate and nicotine-oil, would have given much better control if they had not been exposed to such extensive reinfestation. On the other hand, it is safe to assume that the inferior treatments were actually somewhat poorer than the figures would indicate. This factor was evidently of special importance in the experiments conducted in the Middle West and the Northwest, where the development of the insect extended into a considerable third brood.

Preliminary results of the statistical analysis indicate that conditions in most of the experiments were extremely variable, and that differences in infestations between plats to be compared must be fairly wide to be considered significant, and that narrow apparent differences between materials should not be used as a basis for conclusions as to their exact relative value.

Field Tests of Organic Materials at Kearneysville, W. Va.

The tests of organic materials under Eastern conditions were carried on at Kearneysville, W. Va., as a cooperative project with the West Virginia Experiment Station. This Bureau is very much indebted to Director F. D. Fromme and Professor L. M. Peairs for making possible the employment of Edwin Gould, of the University Experiment Farm at Kearneysville, for the season's work, and for furnishing the use of the facilities of the University Farm, which was used as headquarters. Dr. F. J. Schneiderhan, in charge of the Farm, was extremely helpful in many ways.

The experimental plats were located in the R. W. Border orchard, one and one-half miles east of the station. Twenty acres of the orchard were leased for the project. The trees in this block were 24 years old; about 1/3 of them were Yorks and 2/3 Staymen. The trees were of average size and in good vigor. Light pruning had been practiced, consequently the trees were rather thick, often making a thorough job of spraying difficult. The orchard was in sod and was mowed twice during the season.

The codling moth infestation was moderate, but was severe enough to give clearcut comparisons of materials. It was surrounded on three sides by orchards. A packing shed in the east orchard was a source of codling moth infestation and resulted in a more dense population in those plats adjoining that section than in those located in some other part of the block. This varying population was also evident in other sections of the block.

The orchard was divided into three sections; one of Yorks and two of Stayman. Most of the plats consisted of 8 trees each, 4 trees in each of two rows. With the exception of treatments Nos. 34, 35, 36 and 43, the various plats were replicated 3 times, once in each of the three sections. The above four treatments were replicated only twice, once in the York section and once in a Stayman section wherever possible. In each replicate plat, three trees of each main variety in the experiment - Yorks and Stayman - were selected and marked as count trees.

The season was about normal for the Shenandoah Valley, the calyx spray in the experimental orchard being applied during the period May 11 to May 14.

All plats were sprayed with lead arsenate in the petal fall application, and most of the experimental treatments were started in the first cover spray, a plat sprayed with lead arsenate throughout being the standard of comparison. Flotation sulphur was used as the fungicide in the first cover spray, after which time no fungicide was used, as such.

The treatments and the results obtained are given in the following table.

Field Experiments with Organic Materials for Codling Moth Control
Kearneysville, W. Va. - 1934.

Plat No.	Material tested (pounds per 100, unless otherwise stated)	Used with	Schedule	Worm injuries: Wormy fruit	Fruit free from worms and stings	Worms per 100 apples	Stings per 100 apples
				percent	percent		
26	Lead arsenate 3-100	Alone	Regular[1]	1.0	84.2	1.2	18.6
27	Nicotine sulphate (40% nicotine) 1-1200	White oil, .5%	Do.[2]	10.2	74.5	13.4	22.4
28	Do.	Do.	7-day[2,3]	1.9	91.1	2.0	8.2
29	Processed nicotine-bentonite (8% nicotine) 3-100	Alone	Regular	23.5	62.6	29.7	23.0
30	Do. 3-100	White oil, .5%	Do.	20.6	68.9	25.9	17.0
31	Do. 3-100	Alone	7-day	13.4	74.5	15.4	16.7
32	Do. 6-100	Do.	Regular	16.4	70.2	19.7	17.9
33	Do. 6-100	Do.	7-day	4.3	88.1	4.6	9.9
34	Nicotine tannate, New Jersey[4]	Alone	Regular	16.5	67.6	21.3	22.9
35	Do.	Bentonite-sulphur	Do.	12.4	72.2	15.2	21.2
36	Do.	Alone	7-day	4.4	83.2	4.8	15.3
37	Ground derris root 1 part, kaolin 3 parts, containing 1% rotenone 10-100	Do.	Regular	49.7	43.5	82.4	34.5
38	Do. 10-100	Do.	7-day	36.9	49.2	57.4	33.1
39	Do. 10-100	White oil .5% [2]	Do.	28.8	60.9	40.5	20.5
40	Do. 5-100	Do.	Do.	30.6	59.4	42.4	19.7
41	Nicotine-bentonite (8% nicotine) with copper 6-100	Alone	Do.	6.9	83.1	7;6	12.0
42	Ground pyrethrum 1 part, kaolin 3 parts, containing .25% pyrethrins 10-100	White oil, .5%[2]	Do.	30.7	58.3	43.5	23.1
43	Phenothiazine 3.7 lbs. 1st & 2nd cover; 4 lbs-100 remainder	Bentonite 4 lbs. Fish oil 1 qt.	Regular	36.0	51.5	50.6	26.3

[1] Regular schedule - 5 cover sprays, final application Aug. 2-7

[2] Beginning with the 2nd cover spray on regular schedule (1st cover spray, lead arsenate)

[3] 7-day schedule - 11 cover sprays, final application Aug. 23

[4] Nicotine tannate, N.J. formula - 1 pint free nicotine (50% nicotine) and 3 pints of tannic acid in 100

SPRAY INJURY

No serious fruit or foliage injury was caused by any of the materials or combinations used in this series of treatments. Some injury resulted from the phenothiazine-bentonite-flotation sulphur-fish oil combination used in the first cover spray in plat No. 43. This may have been caused by the flotation sulphur combination, since the subsequent treatments did not result in additional injury. The nicotine tannate-bentonite-sulphur combination, as used in plat No. 35, resulted in some fruit injury. The injury was of the typical sulphur type. Sulphur sprays cannot be used with safety in the late summer sprays in this section.

SPRAY RESIDUE

The residues deposited by the various materials and combinations, even though for the most part nonpoisonous, resulted in severe commercial losses. The fruit from the nicotine-oil plat, No. 28, showed a dull oily finish and did not color well. The fruit from all the pyrethrum-kaolin and the derris-kaolin plats carried a very heavy residue at harvest time. This could not be removed by any of the standard residue removal methods, and the fruit was unmarketable except to by-product plants. The fruits from the nicotine-tannate plats showed a dark residue which required washing to remove. The fruits from the phenothiazine plats carried a very heavy black residue which could not be removed by commercial methods. When the residue was removed, the fruit showed a blotched appearance due to the discolored areas under the heavy dark residue.

The nicotine-bentonite plats were the only ones which did not leave an objectionable residue at harvest time. These materials gave the highest quality and best finished fruit of any of the materials used.

Field Tests of Organic Insecticides at St. Joseph, Mo.

Experiments in the Middle West were conducted at St. Joseph, Mo., in cooperation with the Missouri Experiment Station, with Howard Baker in immediate charge. The work was carried on in a 20-acre block of Jonathan and Ben Davis in the Kenmoor orchard, a few miles south of St. Joseph.

The season as a whole started normally, the pink and calyx sprays being applied at about the usual time. Almost immediately, or soon after the first of May, the weather turned unseasonably warm and dry and remained so with but one brief interruption (June 8-12) until August 15, when the arrival of rains and cooler weather broke the drought. A heavy hail the morning of June 9 caused much damage in the experimental block. The trees suffered severely during the extended period of extreme drought. Many of the weak or injured trees, especially the older trees of the Ben Davis variety, died. The fruit also suffered and made practically no growth during the period June 15 to August 15.

The spring was unusually favorable for maximum codling moth development with the result that moths came out in large numbers almost without interruption from the time the first ones appeared (May 8) until June 2. The bait trap records show that there were 3 good broods of the codling moth. Spring-

brood moths were present in greatest numbers from May 11 to June 2, first-brood moths from June 25 to July 23, and second-brood moths from July 30 to August 10. It is believed that the number of second-brood moths was severely restricted by the effects of weather conditions on oviposition on the part of first-brood moths.

Despite the heavy first brood damage in many plats, the heavy moth population present, and the presence of many cracks and scars due to the serious hail injury which would ordinarily serve as favored entrance places for new worms, worm damage during July and August was very light and far below normal expectations. It seems evident that the high temperatures, low humidities, or some combination of both, worked to reduce or prevent normal oviposition by the moths during the period of extreme heat and drought. If eggs were laid, they apparently dried up and dropped off, since they were scarce during this period. The condition reported upon in this paragraph, as applying to the experimental plats, was general throughout the Missouri River Valley.

After the arrival of rain and cooler weather in mid-August, worm injury began to increase and this injury continued until the end of harvest, being heavier, however, from about September 5 to September 20 than in any other period of similar duration after July 5.

Because of the late start on the work, all plats were given a calyx spray of lead arsenate, with summer-strength lime-sulphur. Bentonite-sulphur was used as a fungicide in the first cover spray, after which no fungicide was used, as such. The mineral oil used was a commercially prepared white oil emulsion.

On account of the dying of so many Ben Davis trees, counts are reported on the Jonathan variety only. The fruit was so badly scarred by the hail that no record was made of the "sting" injuries caused by the codling moth.

Plat 1 was repeated 6 times, plats 2 and 8 were in triplicate, and 9-20 were in duplicate. The materials tested, and the results obtained, are given in the following table:

Field Experiments with Organic Materials for Codling Moth Control, Jonathan Variety, St. Joseph, Mo., 1934

Plat No.	Material tested (pounds per 100 gallons, unless otherwise stated)		Used with	Schedule	Worm injuries: Wormy fruit	Worm injuries: Worms per 100 apples
					Percent	
1	Lead arsenate	3-100	Alone	Regular[1]	31.5	43.6
2	Nicotine sulphate (40% nicotine)	1-1200	White oil, .5%[2]	Do.	30.1	42.4
3	Do.		Do.	7-day[3]	22.9	30.4
4	Processed nicotine-bentonite (8% nicotine)	3-100	Alone	Regular	69.3	122.0
5	Do.	3-100	White oil .5%	Do.	37.7	51.8
6	Do.	3-100	Alone	7-day	75.9	118.4
7	Do.	6-100	Do.	Regular	59.7	95.3
8	Do.	6-100	Do.	7-day	48.4	72.2
9	Nicotine tannate, New Jersey formula[4]		Do.	Regular	71.6	131.3
10	Do.		Bentonite-sulphur	Do.	53.3	82.3
11	Do.		Alone	7-day	52.3	78.0
12	Ground derris root, 1 part, kaolin 3 parts, containing 1% rotenone	10-100	Do.	Regular	84.2	172.9
13	Do.	10-100	Do.	7-day	88.7	165.2
14	Do.	10-100	White oil .5%	7-day	53.0	76.4
15	Do.	5-100	Do.	Do.	49.1	81.3
16	Processed nicotine bentonite (8% nicotine) with copper	6-100	Alone	Regular	48.9	69.6
17	Ground prethrum, 1 part, kaolin 3 parts, containing .25% pyrethrins	10-100	White oil .5%	7-day	54.9	86.1
18	Lead arsenate 3-100 in 1st brood; nicotine-bentonite 6-100 remainder of season		Lead used alone Nicotine-bentonite with white oil .5%	Regular	37.1	58.3
19	Do.		Lead used alone Nicotine-bentonite with fish oil 1/4%	Regular	39.7	59.2
20	Lead arsenate 1st brood; derris-kaolin 10-100 rest of season		Lead used alone Derris with fish oil 1/4%	Regular	64.4	111.2

[1] Regular schedule - nine cover sprays applied at approximately ten to twelve-day intervals.

[2] All oil applications were started with the 2nd cover spray.

[3] 7-day schedule -fourteen cover sprays applied at approximately 7-day intervals.

[4] Nicotine tannate, N.J. Formula - 1 pint of free nicotine (50% nicotine) and 3 pints of tannic acid in 100 gallons (reduced to 2 pints of tannic acid in latter part of season.)

In early summer a browning of the leaves appeared in all plats receiving oil. This was believed to be due to the use of oil too soon after sulphur, complicated by high temperatures. A somewhat similar injury developed in the nicotine tannate plats, and was believed to be due in part to an excess of tannic acid in the formula. The proportion of tannic acid was later reduced.

Measurements showed that the average size of leaves from the nicotine-bentonite-oil plats was 10 percent smaller than that of leaves from the lead arsenate plats, and that the average size of leaves from the nicotine sulphate-oil plats, both those sprayed on the 7-day schedule and those sprayed on the regular schedule, was about 16 percent smaller than that of leaves from the lead arsenate plats. It would appear, therefore, that there was some reduction in size of foliage due to the use of nicotine-bentonite with oil and a greater reduction due to the use of nicotine sulphate with oil.

In early summer serious fruit injury developed in the trees sprayed with nicotine tannate plus bentonite-sulphur. An excess of tannic acid in the formula may have contributed to this injury. With the reduction in the amount of tannic acid used there was no apparent increase in the amount of this injury. Late in the season small brown specks appeared on a small number of apples sprayed with nicotine tannate. During the period of extreme heat and drought many apples were badly sunburned in all plats. This injury was the most severe in the plats, receiving oil, especially in the nicotine sulphate-oil plats, where no kaolin or other solid material was used with the insecticide.

As the harvest season approached, some of the fruit in the experimental block presented an unsightly appearance due to treatment. Fruit which has been sprayed with nicotine sulphate-oil was especially unsightly, being a dull, dirty green in color. Fruit sprayed with derris-oil, and to a lesser extent that sprayed with pyrethrum-oil and derris alone, presented a poor appearance due largely to the accumulation of a heavy spray coating. In the end, however, due to the unusually favorable conditions for maturing and coloring the fruit that prevailed during late August and September, these differences in appearance due to treatment were, for the most part, erased.

Field Tests of Organic Insecticides at Parma, Idaho.

The most extensive field experiments in the Northwest were conducted at Parma, Idaho, in cooperation with the Idaho Agricultural Experiment Station, which furnished the use of the facilities available at its Parma substation, and granted R. W. Haegele leave of absence to take immediate charge of the work, under the general direction of E. J. Newcomer, of the Yakima, Wash., station. The Bureau of Entomology and Plant Quarantine is very much indebted to Director E. J. Iddings and to Professor Claude Wakeland for their helpful cooperation. Dr. R. H. Robinson, of the Insecticide Division (on leave from the Oregon Agricultural Experiment Station) was headquartered at Parma and participated actively in the work.

The orchard leased for this experiment, known as one of the E. G. Johnson orchards, was located about seven miles northwest of Parma. The trees were set out in 5-acre blocks separated by so-called streets about 40 feet wide, the distance between the tree rows in the blocks being 30 feet. The North Orchard of this experiment was planted to two varieties, there being fifteen rows of Winesaps and twelve rows of Jonathans. The South Orchard

consisted of two blocks and is designated as the Southwest and Southeast Orchards. Each block included three rows of Rome Beauty trees, four rows of Winesaps and four rows of Jonathans.

Treatments 1 to 11 and 17 were plotted in the North Orchard with eight replications or plats for each, four on each of the two varieties. Treatments 101 and 12 to 16 were plotted in the Southwest Orchard with six replications,or two on each of the three varieties. The Southeast Orchard was sprayed with lead arsenate the first four cover sprays extending through the period of the first brood. The last four sprays were treatments 21 to 32, mostly with six replications or two on each variety. In the North Orchard, records were taken from one tree in each plat, and in the two south orchards, records were taken from two trees in each plat. The replications were arranged at random. There were four or more trees in each plat excepting in a few cases where missing trees reduced the number to three. The plats did not include any trees next to the sheds or buildings located along the street between the north and south orchards.

The orchard is about 20 years old made up of healthy well cared for trees in full bearing. The trees were properly pruned in the spring and received a dormant spray for scale control. The orchard management during the season conformed to approved orchard practice in the district. It was irrigated four times, sufficient to insure proper growth of the fruit and wood. The fruit was thinned between May 23 and June 7, to reduce the number of apples on a tree to the size crop best suited for size and quality of fruit, and to eliminate "doubles" or "clusters". Where apples hang together as "doubles" or in "clusters", the larvae gain entrance to the apples at the points of contact where it is difficult to apply the spray material. The crop was not heavy on the orchard, but set to an excessive degree in large clusters, an unusual condition. After these clusters were broken the resulting crop was rather light.

The loose bark was scraped from the trees in early summer and the trunks banded with two-inch strips of corrugated paper. Thousands of larvae that would otherwise seek protection for cocooning in the loose bark, entered the corrugated paper bands to spin cocoons. These bands were not treated since they are to be removed for the collection of the larvae.

The spray outline was arranged to have certain treatments applied on the regular spray schedule of the district as determined by the activity of the moths. For the last few years,five to seven applications have sufficed to give control. The other schedule called for 7-day applications, providing a maximum number of sprays for comparison to the regular schedule with a minimum number. It was first planned to apply six and ten cover sprays for the two schedules, but the spring of 1934 opened up about three weeks ahead of normal, and it developed that a commercial spray schedule of nine to twelve applications was necessary in this section to produce a clean crop. The program for the experiment, therefore, developed to eight applications for the regular schedule and twelve for the 7-day. An additional spray might have been applied in August, but the condition of the crop did not warrant it.

Dr. R. H. Robinson, chemist for the project, assisted in supervising the correct preparation and the mixing of the materials to advantage. Dr.

Robinson tested the alkalinity of the spray water and advised the addition of 56 cc. sulphuric acid to 300 gallons of water to give a neutral spray. In order to prepare a neutral oil emulsion, he also advised the use of a skim milk formula in making the emulsion. Dr. Robinson's advice was followed in the preparation of the nicotine tannate sprays, and he prepared and mixed the material for treatment No. 30.

In general, the procedure for mixing the spray materials in the sprayer tank were as follows. The tank was filled two-thirds full of water when 56 cc of sulphuric acid was added. The powdered organic spray materials, first mixed with water to a free-flowing consistency, were then added. When oil was used, the required amount of oil emulsion was stirred into the wetted organic mixture before adding to tank. For the nicotine tannates, the sulphuric acid was added to the tank one-third full of water, the tannic acid added next, and then the free nicotine, and where the bentonite-sulphur was used it was added last. The nicotine sulphate was added to the tank after neutralizing the water, and then the oil emulsion. The tank agitator was kept running while all sprays were mixed.

Dr. Robinson's formula for the preparation of the oil emulsion was as follows:

"Add 2 gallons of water to 12 ounces of powdered milk, stirring in a little at a time until a smooth paste is formed, then adding the remainder. Transfer mixture to the mixer and with agitator going, pour in slowly through funnel 4 gallons of oil. Mix for about 5 minutes to produce a creamy oil-in-water emulsion. This contains about 65% oil. For .5% strength in spray, use 3 quarts of this emulsion to 100 gallons."

The oil used was a summer type spray oil 90% unsulphonatable and 64 to 70 seconds viscosity at 100° F., Saybolt Universal.

The details of the treatments are given in the following tables:

Field Experiments with Organic Materials for Codling Moth Control
North Orchard, Parma, Idaho - 1934
(Average of four replicates on Jonathans and four on Winesaps)

Plat No.	Material tested (pounds per 100 gallons unless otherwise stated)	Used with	Schedule	Worm injuries: Wormy fruit	Fruit free from worms and stings	Worms per 100 apples	Stings per 100 apples
				Percent	Percent		
1	Lead arsenate 3-100	Alone	Regular[1]	58.2	2.6	139.3	374.0
2	Nicotine sulphate (40% nicotine) 1-1200	White oil .5%	Do.	65.6	10.5	130.5	110.0
3	Do.	Do.	7-day[2]	36.2	27.2	62.0	83.7
3x	Processed nicotine-bentonite with copper (8% nicotine) 6-100	Alone	Regular	94.4	2.6	277.9	39.4
4	Processed nicotine-bentonite (8% nicotine) 3-100	Do.	Do.	92.3	1.1	281.2	40.1
5	Do. 3-100	White oil .5%	Do.	80.4	7.4	178.7	43.0
6	Do. 3-100	Alone	7-day	92.8	2.0	266.8	41.0
7	Do. 6-100	Do.	Regular	87.2	5.9	197.7	52.7
8	Do. 6-100	Do.	7-day	79.8	8.2	158.2	63.0
9	Nicotine tannate (tannic acid 2 pts-100 gal.; 50% free nicotine 1 pt.-100 gal.)	Do.	Regular	81.7	5.4	195.6	75.6
10	Nicotine tannate (tannic acid 2 pts-100 gal.; 50% free nicotine 1 pt.-100 gal.)	Bentonite-sulphur 2-100	Regular	67.6	15.0	136.8	59.0
11	Do.	Alone	7-day	70.4	12.0	147.4	66.4
17	Ground pyrethrum 1 part, kaolin 3 parts, containing .25% pyrethrins 10-100	White oil .5%	Do.	89.8	6.7	228.3	24.0

[1]Regular schedule - 8 cover sprays, final application July 30 to August 5.

[2]7-day schedule - 12 cover sprays, final application August 9-10.

Field Experiments with Organic Materials for Codling Moth Control
Southwest Orchard, Parma, Idaho - 1934
(Average of two replicates each on Jonathan, Winesap, and Rome)

Plat No.	Material tested (pounds per 100 gallons)		Used with	Schedule	Worm injuries			
					Wormy fruit	Fruit free from worms and stings	Worms per 100 apples	Stings per 100 apples
					Percent	Percent		
101	Lead arsenate	3-100	Alone	Regular	68.0	2.6	266.9	317.3
12	Ground derris root, 1 part, kaolin 5 parts, containing 1% rotenone	10-100	Do.	Do.	98.5	0.7	416.3	27.9
13	Do.	10-100	Do.	7-day	97.4	1.4	386.6	20.5
14	Do.	10-100	White oil .5%	Do.	95.4	2.1	307.4	26.7
15	Do.	5-100	Do.	Do.	95.3	2.3	308.9	25.4
16	Ground cubé root 1 part, kaolin 3 parts, containing 1% rotenone	10-100	Alone	Do.	98.6	1.0	481.9	16.9

Field Experiments with Organic Materials for Codling Moth Control
Southeast Orchard, Parma, Idaho - 1934
(Average of two replicates each on Jonathan, Winesap and Rome.)

Plat No.	Material tested in cover sprays 5-8 (Lead arsenate 3-100 in calyx spray and covers 1-4)		Used with	Worm Injuries			
				Wormy fruit	Fruit free from worms & stings	Worms per 100 apples	Stings per 100 apples
				Percent	Percent		
21	Lead arsenate	3-100	Alone	66.3	2.4	181.6	318.2
22[1]	Nicotine sulphate	1-1200	White oil .5%	69.9	6.6	154.7	155.8
23	Processed nicotine-bentonite (3% nicotine)	3-100	Do.	77.4	6.7	196.3	92.9
25	Ground derris root, 1 part, kaolin 3 parts, containing 1% rotenone	5-100	Do.	88.2	2.1	315.9	110.7
26	Ground cubé root 1 part, kaolin 3 parts, containing 1% rotenone	5-100	Do.	91.3	1.6	304.9	131.8
27	Ground pyrethrum 1 part, kaolin 3 parts, containing .25% pyrethrins	5-100	Do.	92.6	1.8	328.3	105.9
30	Anabasine sulphate 40%, diluted to contain .25% anabasine		Bentonite 4-100 White oil .5%	91.5	3.3	292.3	88.1
31	Derris with kaolin, containing 6% rotenone	3-100	White oil .5%	82.5	5.1	224.8	126.6

[1] Jonathan and Winesap only.

In addition, a limited test was conducted of phenothiazine in cover sprays 5 to 8 on the Rome variety. The single count tree used showed 284 worms per 100 apples, as compared with 241 worms per 100 apples on Rome trees sprayed with lead arsenate throughout.

Injury to fruit or foliage that developed during the season as a result of the materials used was, in most treatments, of little importance. A few of the materials, however, caused injury of a serious nature.

Fruit injury was noticeable on the nicotine tannate treatments. The apples developed tiny black specks early in the season. On a few plats this injury was very distinct, from 10 to 50 percent of the apples being marked. By July 30, but little of the injury seemed important, although on some of the trees the specks on the fruit persisted through until harvest. In treatment No. 10 where bentonite-sulphur was used with nicotine tannate, apples at harvest were very much smaller than on other plats, this treatment apparently checking the growth of the fruit. The apples did not color well and the residue was very difficult to rub off. The nicotine tannate alone on the 12-spray schedule in treatment 11 left a residue ring that rubbed off with difficulty. In the 8-spray nicotine tannate treatment, No. 9, oil was added to half of the plats in the 6th, 7th, and 8th sprays, and here the spray coverage was very spotty, the residue spots when rubbed off showing absence of color on fruit.

The nicotine sulphate and oil, where used 12 times on treatment No. 3, caused a severe oil burn on the Jonathan apples, but this was confined to the apples in the upper half of the tree. The Winesap variety did not show any fruit burn from the same treatment.

Heavy residues were left on the fruit from the pyrethrum, derris, and cube 12-spray treatments, but apparently did not inhibit coloring. The phenothiazine left very spotted fruit after the residue was rubbed off.

Foliage injury was more general throughout the orchard, probably being due in most cases to the continuous use of oil in the 12-spray treatments. Much of this injury was noted on cupped leaves and on the south and west sides of the trees. This type of injury was very scattering and was not of a serious nature.

The nicotine tannate with bentonite-sulphur in treatment No. 10 caused a severe burning of foliage throughout the trees. The injury developed rapidly during July, and the trees remained conspicuous from the burned foliage until the end of the season. This foliage injury probably influenced the size of the fruit on these trees as already noted.

All of the nicotine sprays were disagreeable to the men operating the spray nozzles. The spray was irritating to the eyes and nose and caused coughing and sneezing. The men could not continue to work unless they kept almost entirely out of the mist or spray. The nicotine tannates were extremely irritating, and it was necessary to apply these sprays, as well as the nicotine sulphates, in the morning. During July and August, the warm mornings made the use of these materials more disagreeable. The nicotine bentonite was much less irritating to the sprayers, but in mixing the material for the spray tank, one needed to avoid the dust.

Only one worker seemed to be affected by the pyrethrum, and he complained of a slight dizziness after mixing the dry material to a paste preparatory to adding to spray machine. It seems probable that he did not avoid the dust as he might easily have done. Those men doing the spraying did not report any ill effects from the pyrethrum spray.

The derris and cube dust tended to be somewhat nauseating, and the derris sometimes caused a temporary numbness of the lips and tongue on getting in the mouth. Two workers reported that derris caused attacks of hay-fever. One was bothered with hay-fever at intervals during the summer, and the other only by temporary attacks of sneezing while spraying. Neither was incapacitated for work. The use of the derris for half a day at a time, and continued for two or three days, caused a grogginess and nausea to the operators. A change to other materials caused the sickness to clear up. In no case was a worker rendered unable to continue at work because of sickness from the spray materials.

Tests of Organic Insecticides at Hood River, Oreg.

Cooperative experiments including a part of the general outline were conducted at Hood River, Oreg., under the direction of Leroy Childs. The tests were conducted on the Yellow Newtown variety in the experimental orchard at the Hood River Experiment Station, where tests of a similar character have been in progress for a number of years. In this orchard codling moth populations have been kept at a relatively low point for a number of years.

Seasonal conditions in the Hood River Valley during the past year were somewhat abnormal in that the season was approximately one month earlier than average. This condition caused moth activities to begin approximately a month earlier than usual. Regardless of the fact that trap records for spring brood moth activities had equaled approximately 75 percent of the previous season's catch, first brood worm activities were very limited. Throughout this period eggs of the codling moth were found with difficulty in the experimental orchard, and it seems probable that temperatures were not favorable for heavy egg deposition, regardless of the fact that first-brood moths were present for approximately three months.

The materials tested, and the results obtained, will be found in the following table:

FIELD EXPERIMENTS WITH ORGANIC MATERIALS FOR CODLING MOTH CONTROL. HOOD RIVER, OREGON, 1934.

Plat No.	Material tested (lbs. per 100 gallons unless otherwise stated.) Lead arsenate 3-100 used in calyx spray throughout.)	Schedule	Worm Injuries: Fruit free from worms & stings percent.	Wormy fruit percent	Stung Fruit percent
1	Lead arsenate 3-100	Regular 1/	96.1	.8	3.2
1a	Do.- with white oil 1% in 3rd and 4th covers	Do.	95.2	.8	4.3
6	Processed nicotine-bentonite 8% nicotine - 3-100	7-day 2/	95.3	3.0	2.2
7	Do. 6-100	Regular	92.6	4.1	3.4
8	Do. 6-100	7-day	96.9	1.2	1.9
9	Nicotine tannate 3/	Regular	86.8	8.7	4.8
10	Do. - plus bentonite-sulphur	Do.	90.6	5.2	4.1
13	Ground derris root, 1 part, kaolin 3 parts, containing 1% rotenone 10-100	7-day	93.8	4.2	2.3
16	Ground cube root, 1 part, kaolin 3 parts, containing 1% rotenone, 10-100	Do.	93.5	2.5	2.6
17	Pyrethrum 1 part, kaolin 3 parts, containing .25% pyrethrins, 10-100	Do.	91.1	6.0	3.5
-	Unsprayed 4/	-	75.0	21.0	5.9

1/ Regular schedule: 5 cover sprays, last application Aug. 14-18
2/ 7-day schedule: 10 cover sprays, last application Aug. 14-15.
3/ Nicotine tannate = 50% free nicotine 1 pt. - 100 gal. plus tannic acid 850 cc per 100 gal.
4/ Unsprayed in one replicate only; located in portion of orchard containing the lightest infestation.

No serious injury developed in most of these experiments. In plat 1A, sprayed with a white oil with lead arsenate in the 3rd and 4th covers, a large proportion of the apples showed characteristic oil injury at the calyx ends. In plats 9 and 10, sprayed with nicotine tannate, the lower surfaces of the apples showed a discoloration of the wax. This material was readily removed, but its presence detracted from the general appearance of the fruit. Occasional clusters of small black spots were also present. Heavy deposits of residue were present on the fruit in plats 13, 16, and 17, sprayed with derris, cube, and pyrethrum with kaolin.

Tests of Organic Materials on Pear at Talent, Oreg.

The organic materials were tested in the control of codling moth on pears in a cooperative project with the Oregon Experiment Station at the Branch Station at Talent. L. G. Gentner, of the Talent Branch Station, was in immediate charge.

The experiments were conducted in a 25-year-old Bartlett orchard. There were not enough trees available in one block for all treatments, therefore, it was necessary to use two blocks in different parts of the orchard. Block No. 1 contained four plats and Block No. 2 twelve plats. The lead arsenate check plat was included in each block. Each plat contained six trees in three replications of two trees each.

The 1934 codling moth season was an unusually early and long one. It was necessary to apply a calyx and five cover sprays on Bartlett pears to obtain control, when normally only a calyx and three cover sprays are necessary.

All plats received a calyx and first cover spray of lead arsenate, because the organic materials had not yet arrived. In Block No. 2 the calyx spray had already been applied by the grower. Plats 13 to 16, inclusive, received a third cover spray of nicotine-bentonite, 3 lbs. in 100, instead of derris or cube, because of delay in the delivery of the materials intended for these plats.

On those plats where oil was required in the third cover spray, a commercial emulsion of an oil having a viscosity of 72 was used. In all subsequent applications a home-made emulsion of an oil having a viscosity of 72-75, sulfonation test of 90, was used. The emulsion was made up according to the same formula as that used in the experiments at Parma, Idaho.

The following table gives detailed information on the materials used, and the results obtained.

Field Experiments with Organic Materials for Codling Moth Control on Bartlett Pears - Talent, Oregon - 1934

Block	Plat No.	Material tested (pounds per 100 gallons, unless otherwise stated)		Used with	Schedule	Wormy fruit
						Percent
I	1	Lead arsenate	3-100	Alone	Regular[1]	4.5
	2	Nicotine sulphate (40% nicotine)	1-1200	White oil .5%	Do.	3.7
	3	Do.	1-1200	Do.	7-day[2]	2.4
	17	Ground pyrethrum 1 part, Kaolin 3 parts, containing .25% pyrethrins	10-100	Do.	Do.	4.8
II	1	Lead arsenate	3-100	Alone	Regular	5.6
	4	Processed nicotine-bentonite (8% nicotine)	3-100	Do.	Do.	12.8
	5	Do.	3-100	White oil .5%	Do.	5.1
	6	Do.	3-100	Alone	7-day	9.5
	7	Do.	6-100	Do.	Regular	11.8
	8	Do.	6-100	Do.	7-day	5.5
	12[3]	Ground derris root 1 part, Kaolin 3 parts, containing 1% rotenone	10-100	Alone	Regular	15.2
	13[3]	Do.	10-100	Do.	7-day	16.3
	14[3]	Do.	10-100	White oil .5%	Do.	11.5
	15[3]	Do.	5-100	Do.	Do.	10.9
	16[3]	Ground cubé root 1 part, Kaolin 3 parts, containing 1% rotenone	10-100	Alone	Do.	14.2
	18	Processed nicotine-bentonite (8% nicotine) with copper	3-100	Do.	Regular	11.2

[1]Four cover sprays of the material tested, following a calyx and 1st cover of lead arsenate.

[2]Seven cover sprays of the material tested, following a calyx and 1st cover of lead arsenate.

[3]Because of delay in receiving materials, nicotine-bentonite 3 lbs. in 100 gallons was used in 3rd cover spray.

No injury of any kind to fruit or foliage was observed in any of the plats, as the result of spraying with the organic substitutes for lead arsenate. Although the use of one-half of one percent of white oil in five cover sprays appeared to have a slight retarding effect upon the ripening of Bartlett pears, this is probably of no consequence, and the quality of the fruit was not affected.

In plats 2 and 3, where nicotine sulphate was used, and 4, 5, 6, 7 and 18, where nicotine-bentonite was used, there appeared to be no visible residue on

the fruit at harvest time. However, in plats 12, 13, 14, 15, 16, and 17, where derris root, cube root and pyrethrum were used with kaolin, there was a very heavy residue. In those plats receiving applications at regular timing, the residue was in the form of large, coarse spots or blotches, while in those receiving applications at 7-day intervals the spots had run together more or less, making a more uniform covering. On those fruits which developed a red cheek the heavy residue prevented uniform coloring.

A visible residue remained after washing on the fruit from plats 13, 14 and 15, in which derris root with kaolin was used at 7-day intervals, with or without oil. An acid wash as strong as 3 percent at a temperature of 100° F. failed to remove this visible residue. Dr. Robinson took some of these lots to Portland where he washed them in a sodium silicate wash, which removed all traces of the residue. Practically all of the packing houses in the Rogue River Valley use a hydrochloric acid wash for cleaning fruit.

Discussion of Results of Large-Scale Field Testing of Organic Materials

The materials used in these experiments can be classified in order of effectiveness in three groups.

1. The most effective materials tested	-	Lead arsenate (the standard of comparison) Nicotine - oil
2. Materials intermediate in effectiveness	-	Nicotine tannate Nicotine - bentonite
3. Ineffective materials	-	Derris - kaolin Cube - kaolin Pyrethrum - kaolin Phenothiazine

Lead arsenate continues to be the standard of effectiveness, although in certain experiments the results were quite unsatisfactory. This was, however, in part due to the fact the lead arsenate plats were surrounded by very inferior treatments and there was undoubtedly a considerable migration of moths during the season from the poorly protected plats into the plats sprayed with lead arsenate. This was especially conspicuous in the experiments at Parma, Idaho, where a heavy flight of moths took place during most of August.

Nicotine-oil on the regular schedule gave results averaging perhaps a little poorer than those obtained with lead arsenate alone, although in many cases the two treatments appeared approximately equal. When applied on a schedule calling for more frequent applications, the oil-nicotine mixture appeared more effective than lead arsenate alone on the regular schedule, especially considering the reduction in the number of stings on the nicotine-sprayed apples. A number of factors, however, make it inadvisable to recommend a shift to a nicotine-oil combination. In some cases its use results in direct injury to foliage and fruit, as well as a stunting of the leaves and fruit, and

in some cases in interference with the proper coloring of the fruit. There is serious question just how many applications of oil can be safely made to apple trees. The oil is incompatible with sulphur fungicides, which must be used in humid regions, at least in the early season on varieties subject to diseases. A full season's program including frequent applications of nicotine and oil is also extremely expensive, amounting to a considerable proportion of the value of the prospective crop.

The results with nicotine tannate and nicotine bentonite were definitely inferior to those obtained with lead arsenate and with the oil-nicotine mixture. The factory-processed nicotine-bentonite, which was used in most of the experiments, apparently contained too much of the wetting agent or an unsuitable material for this purpose, since it was observed in a number of experiments that there was a very heavy run-off of material. Although these results were not especially favorable, the high toxicity which nicotine is known to possess, the favorable results obtained from the use of the nicotine-oil combination and the good control which has been reported from experiments with nicotine-bentonite and nicotine tannate by the New Jersey Experiment Station give reason for a belief that the fixed nicotine combinations are worth further investigation.

Among the other organic materials tested, derris received the greatest amount of attention. In no case did the derris root-kaolin mixture alone give anything resembling control. The addition of oil gave the mixture a certain degree of effectiveness, but this was probably due to the presence of the oil rather than to any effectiveness in the derris mixture itself. Neither increases in concentration, nor increases in the number of applications, resulted in improvement in control, indicating that the material as used had little or no value.

The experiments with cube root and with pyrethrum were much more limited than those with derris root, but the results indicated that neither of these materials as used were effective in controlling the codling moth.

The experiments with phenothiazine were too limited in extent to justify final conclusions as to its probable effectiveness. The laboratory experiments were largely conducted with a product having a high degree of purity, whereas most of the field work was carried on with material prepared commercially. There is reason to believe that the commercial process may have changed the chemical composition of the substance, and that the substance tested in the field may not have been identical with the one tested in the laboratory. Laboratory tests conducted during the summer have also shown that the presence of bentonite, which was used in the field tests, reduces the toxicity of phenothiazine to the codling moth. In other words, the field testing was somewhat ahead of the laboratory work and the unfavorable results do not mean that this and related materials are not worth further investigation.

Another point brought out very clearly by the experiments was the necessity for avoiding conspicuous residues of any kind, whether poisonous or not. Buyers now discriminate against apples showing signs of visible residue, irrespective of its nature. The mixtures of kaolin with derris, cube and pyrethrum caused very heavy deposits on the fruit, rendering it extremely difficult to market it. The common methods of removing lead arsenate residues proved

ineffective in most cases in removing the mixture containing kaolin. In the case of the Kearneysville experiments, the fruit sprayed with such mixtures, even though much of it was otherwise of a very high grade, had to be disposed of at a cannery.

In certain cases a similar difficulty has been encountered with the nicotine-bentonite mixture, although the deposits left by it were less conspicuous, and the difficulty with this particular mixture was less important than with the kaolin-derris and similar materials.

2. Laboratory Investigations

Allotments of P.W.A. funds were used to strengthen and supplement the laboratory investigations carried on by the regular staff at Takoma Park, Md., and Vincennes, Ind.

Takoma Park, Md.

A great many materials have been tested in the laboratory at Takoma Park. Of these, brief mention will be made of only a few of the more promising ones.

Nicotine - A combination of nicotine-bentonite, giving a relatively water-insoluble compound, seems to offer promise. It is still in the experimental stage, both with respect to the making of the compound as well as the biological testing. Nicotine-bentonite, factory made, is a fairly finely divided powder, whereas the tank-mixed product is in the form of a flocculent precipitate. Laboratory data show that either form has good toxicity when used at a rate of 0.05 percent nicotine in the diluted spray. According to tests with field-sprayed apples, nicotine-bentonite 6 lbs. per 100 gallons was more effective than lead arsenate 4-100 immediately after application, but was ineffective when exposed in the field for 8 days. It appeared that the material contained too much spreader. Tank-mixed nicotine-bentonite apparently gives a very adhesive precipitate, judging by the laboratory tests recently made. In fact, it may be necessary, on this account, to limit the use of this combination to first brood applications.

Derris - This plant material, finely ground, gave very good toxicity under laboratory conditions. Derris-kaolin, applied in the field to apples from which plugs were made for laboratory testing, was not toxic.

Phenothiazine - Although this material did not measure up to expectations in field tests, it warrants further study. According to laboratory tests, a purer form than the commercial product did not have the objectionable color of the latter and under laboratory conditions was toxic when freshly applied.

Dioxy-dinaphthyl-disulphide, benzal dipyridyl amine and 2 chlorodiphenylene oxide have shown good toxicity in laboratory tests but we know nothing of the effect of these materials on foliage.

3-5 dinitro-o-cresol killed 100 percent of the codling moth larvae in our laboratory tests, but has been reported injurious to foliage.

Vincennes, Ind.

Since distilled water was used in the laboratory experiments at Vincennes, the quantities of soaps and spreaders which gave the best results may differ in amount from those needed in the field. Before adoption for field testing, the more promising treatments having to do with spreaders will be repeated with water used for the orchard spraying. The results obtained with the more promising spray combinations are discussed below:

Nicotine-bentonite - In six tests, this material at 2 1/2 lbs. to 50 gallons showed an average efficiency of 75.6 percent in comparison with an average efficiency of 60.7 percent for lead arsenate at 1 lb. to 50 gallons in the same series. The addition of a white oil 1/4 percent gave an average control of 82.9 percent in three tests, improving the efficiency more than did linseed or fish-oil. Both of the latter oils gave poorer results than where the nicotine-bentonite was used alone. The addition of one-fourth percent soy-bean oil increased the average efficiency from 75.3 percent to 83.1 percent in two tests. The raw soy-bean oil was added to the concentrated mixture and agitated before the addition of water to the required volume.

The addition of flotation sulphur increased the control; liquid lime sulphur gave conflicting results in two tests. Materials containing lime greatly increased the control in the laboratory but this was effected by causing a more rapid release of the nicotine, counteracting the effect of the bentonite.

Phenothiazine - This material has been the most promising of any material tested this season. It was used in about 35 tests, some being replicates. When used alone it was difficult to wet and had to be ground into suspension with water in a mortar. With bentonite, lime, or Bordeaux, it was first mixed with the solids after which it could be ground into a water suspension more readily. It was most easily wet when soaps or spreaders were used by diluting the soap to 5 or 10 percent and stirring it into the dry material.

Phenothiazine at one-half pound to 50 gallons had an efficiency of 63.8 percent, at 1 to 50 gallons an average of 85.6 percent, and at 2 to 50 gallons an average efficiency of 91.5 percent.

The quantity of soap used with phenothiazine at 1-50 could be varied from 1/8 ounce to as much as one-fourth pound without having any noticeable effect on control except as noted below. The addition of white oil emulsion and soap increased the control but slightly. Flotation sulphur and soap lowered its efficiency a little. A 2-4-50 copper phosphate-lime mixture, which seems to have some promise as a fungicide, had little effect on the phenothiazine. In most instances regardless of whether or not soap or oil was added to the combination this fungicide caused a slight but possibly not significant decrease in efficiency. The deleterious effect of a 2-4-50 Bordeaux was very striking in direct comparisons with the copper phosphate. The solutions containing copper sulphate averaged approximately 30 percent less effective. Zinc sulphate and lime added to phenothiazine caused severe flocculation and gave poor results. Inclusion of bentonite with phenothiazine, with or without oil, caused a serious lowering of its efficiency.

There were very few stings with phenothiazine treatments. Recent tests indicate that there is no more recovery among larvae that fall off the sprayed fruit than among those falling off of the fruit receiving the nicotine-bentonite treatments. In fact, most of the larvae died on the fruit before beginning an entrance, thus accounting for the small number of stings.

The most striking result of an experiment in which materials were exposed to 4 inches of artificial rain was the persistence of phenothiazine when used with 1/8 ounce soap to 50 gallons. There was less loss of the material than when it was used alone or with the larger quantities of soap. The drop in efficiency for the phenothiazine-copper phosphate-lime-soap combination was greater than for lead arsenate 2-50. However, the former remained more effective than the latter after weathering.

3. Orchard Sanitation and Banding Experiments

Indiana

A large-scale sanitation and banding experiment was conducted at Elberfeld, Ind., under the supervision of L. F. Steiner of the Vincennes Station. A. J. Ackerman, of the regular staff, was in immediate charge.

Approximately 2,000 hours of labor supplied by the emergency funds were required to clean up thoroughly 20 acres or one-half of a square 40-acre orchard. The sanitary measures applied, aside from cultivation and light pruning by the grower, consisted of the removal of all rough bark from the trees, grubbing out of all underbrush and removal of the surface layer of debris and leaves under all trees. Broken branches and split pruning stubs were also removed. All material that might contain hibernating larvae was burned.

The packing house, located in the cleaned half of the orchard, was thoroughly sealed. However, upon later investigation it was found that the 1933 crop of 500 bushels was handled out of doors at the rear of the shed, and this small area no doubt contributed many spring brood moths to the early moth population in the orchard, since the infestation in the region of the packing house was almost as severe as that which developed in the uncleaned areas.

Varieties in this orchard consisted of Collins and Ben Davis in alternate rows. The trees were approximately 30 years old and as a result of poor pruning produced most of the crop in clusters on the outer shell. The grower applied four lead arsenate sprays including the calyx. About three weeks time was used to complete each application. Sprays were usually applied across both cleaned and uncleaned areas at the same time.

The cleaned portion, an area of 16 x 32 tree rows, was bounded on one side by the uncleaned area of the same size and on the other by a young Delicious block of larger size but producing a very light crop.

Three-inch hot-dipped beta naphthol bands prepared by Dr. E. H. Siegler were applied to all except 64 trees in the cleaned area. Untreated bands of three-inch corrugated paper were used on the latter.

In the uncleaned portion of the orchard a square block of 16 trees was selected and the cleanup and banding practices were applied to the alternate trees. The object of this was to gain more information concerning adult movement and to determine if intertree movement of moths would be sufficient to neutralize the effects of such control measures when applied to single trees.

The worm catch in the bands approximated 75,000 to 80,000 in number.

Fruit infestation records were obtained from 90 trees in the orchard. The results are tabulated below.

Worm Injury to Harvested and Dropped Fruit, Elberfeld, Ind.
Buck Orchard Sanitation Experiment

Block	Variety	Cleaned & Banded Worms per 100 apples	Uncleaned & Unbanded Worms per 100 apples	Approx. injury reduction
				Percent
20-acre	Collins	94.4	147.6	36
Do.	Ben Davis	78.4	150.4	47.8
16 trees group	Collins	93.9	106.8	8.7
Do.	Ben Davis	120.9	129.1	6.9

Oregon

An experiment to determine more exactly the influence of banding on the codling moth population under conditions of light to moderate infestation has been started at Hood River, Oreg., as a cooperative project with the Oregon Experiment Station. The scraping and banding were done too late to have much influence on the infestation of the 1934 season, but the Oregon Station intends to carry the experiment over a period of years.

Yakima, Wash.

At Yakima, Wash., experiments to determine the best method of destroying codling moth larvae in picking boxes and cannery lug boxes have been started recently. This work is being done by F. P. Dean, under the direction of E. J. Newcomer, of the regular staff. The work is still in progress, and will include some fumigation work, but a partial report can be made at this time.

In cooperation with the Yakima Fruit Growers' Association, an apparatus for treating boxes with steam has been constructed. This is similar to one in use in a large packing house at Hood River, Oreg., and consists essentially of an insulated wooden tunnel, 40 feet long, with perforated steam pipes in each corner, and with a conveyor in the bottom for running the boxes through the tunnel. The steam pipes are connected to a boiler operated with an oil burner which burns diesel oil. By keeping a steam pressure of 60 to 80 lbs., no difficulty is experienced in maintaining a high temperature in the tunnel while

boxes are being put through it. The temperature remains rather low and fluctuates considerably in the first 8 or 10 feet of the tunnel, because of the cold boxes that are constantly introduced. In the remainder of the tunnel a uniform temperature of as high as 200° or 210° F. can be maintained.

Preliminary laboratory tests with larvae in corrugated cardboard strips showed that they could be killed in 1 minute at 180° F., in 1-1/2 minutes at 160° F., and in 2 minutes at 150° F.

It required some time to heat the boxes to the temperature being tested, so that it was necessary to expose them longer than was indicated by these preliminary tests. Apple boxes, being of light construction, warmed up rapidly. An exposure of 1-1/2 minutes at an average temperature of 184° F. killed 99 percent of the worms in the boxes, and 4 minutes at an average temperature of 173° F. killed 100 percent of the worms. Three minutes at 192° F. also killed 100 percent. The lug boxes used by canneries are of heavier construction, having triangular braces in the corners, and a longer exposure was necessary for these. Four minutes at an average of 202° F. killed 99 percent of the worms, 4 minutes at 183° F. killed 95 percent, and 3 minutes at 192° F. killed 98 percent.

It may be concluded tentatively that at 200° F. apple boxes may be thoroughly sterilized in 2 minutes and lug boxes in 3 minutes. At 180° F., probably 3 and 5 minutes would be required, respectively.

The cost of steaming boxes is low. The diesel oil used for fuel costs 7 cents per gallon, and 2 to 3 gallons per hour are required. This would bring the cost of fuel to about $1.50 or $2.00 per day. It would require from 2 to 6 men at $3.00 per day each to operate the steamer, depending on how it was arranged and when the steaming was done. Since 10,000 apple boxes or 7500 lug boxes could be handled in a day, the total cost for steaming 1,000 apple boxes would be from 75 cents to $2.00, and the total cost for 1,000 lug boxes would be $1.00 to $2.50.

4. Large-scale Bait Trap Experiments

Experiments with the use of bait traps on a large scale were conducted at Orleans, Ind., in cooperation with Purdue University. D. W. Hamilton was in immediate charge, and the work was under the general supervision of L. F. Steiner, of the regular staff of the Vincennes, Ind., Station.

Baits were maintained in each of approximately 1000 trees, in a 35-acre block of Winesap, Jonathan, and Rome. The traps used were chiefly quart-size glass jars. Three baits were used, two ages of each being maintained. The best one consisted of oil on sassafras, one-half cc. per quart of 10 percent dark brown sugar, the second best was citral in a similar sugar solution and the poorest was oil on sassafras in 10 percent blackstrap molasses. After June 27 these baits captured an average of 33, 26, and 12 moths per trap respectively. Uncovered traps appeared better than screen-covered and, as at Vincennes, the cone shaped traps proved still better. Since the baits were renewed at two week intervals large insects accumulating in uncovered traps could not affect the efficiency of the bait as much as when changes were made at longer intervals.

The first part of the spring-brood emergence was missed and the early baits were inferior to those substituted late in June, as shown by early-season experiments at Vincennes. The area was long and narrow, and nearly half of it made up the eight rows bounding the entire south end of the orchard. The codling moth in most orchards is more abundant in the outer rows thus putting the baits at a disadvantage. In spite of these disadvantages, the infestation in the trapped area was somewhat less than that in the untrapped areas. In all, 34,665 moths were captured, 66 percent being females. The infestation figures are given in the following table:

Infestation Records, Bait Trap Experiments,
Troth Orchard, Orleans, Ind. - 1934

Variety	Baited area		Unbaited areas	
	Apples wormy	Worms per 100 apples	Apples wormy	Worms per 100 apples
	Percent		Percent	
Jonathan	26.6	31.7	31.0	50.1
Winesap	6.6	9.4	6.3	8.0
Rome	11.1	14.6	12.3	17.2
Average	14.8	18.6	16.5	25.1

5. Light-trap Investigations

Light-trap investigations were undertaken in two localities--at Geneva, N.Y., and Orleans, Ind.

Light-trap Experiments at Geneva, N. Y.

At Geneva, N. Y., the work was a cooperative project in continuation of the work which the New York Agricultural Experiment Station has had under way for a number of years. The 1934 studies were carried on in the Rome orchard of the Geneva station, where work was inaugurated in 1933. The exceptionally cold winter of 1933-34 had materially reduced the codling moth population, but it was still at a sufficiently high level to insure clear-cut results.

Forty-three Rome Beauty trees formed the plats laid out for the routine experiments. Of these, 27 trees were equipped with a light trap in each tree, and 16 were left unlighted, but sprayed with a varying number of cover sprays of lead arsenate. The trees were distributed among the following 8 categories:

1. Light traps; no lead arsenate.
2. Light traps; calyx spray only.
3. Light traps; 2 cover sprays.
4. Light traps; 3 cover sprays.
5. Light traps; 4 cover sprays.
6. 2 cover sprays; no light traps.
7. 3 cover sprays; no light traps.
8. 4 cover sprays; no light traps.

The light traps were of the electrocutor type. The light sources used included 75 watt incandescent lamps, 60 watt cx lamps, sun-lamps, and coiled mercury vapor tubes. All of these sources proved attractive to the codling moth. In the present report the lighted areas are treated as units, since a detailed analysis of the specific effects of each type of light source has not yet been made. The traps were placed as high in each tree as was possible.

The following table summarizes the more important results obtained:

Infestation Records, Light Experiments, Station
Rome Orchard, Geneva, N.Y. - 1934

Plat treatment	Number caterpillars per 100 apples in bands	Number injured apples per 100 apples	Number injuries per 100 apples	Number clean apples per 100 apples
Light traps without spray	5.2	40.7	60.8	59.3
Spray without light traps (4 cover sprays)	4.1	38.4	66.4	61.6
Combination of 4 sprays and light traps	0.5	7.0	8.5	93.0
3 cover sprays without light traps	6.5	47.3	96.7	52.7

Light-trap Experiments at Orleans, Ind.

At Orleans, Ind., a large-scale test of light traps was carried on, in cooperation with Purdue University. Prof. J. J. Davis aided in arranging for the work and Prof. T. E. Hienton, of the Department of Agricultural Engineering, was very helpful in assisting in working out the details of the electrical installation. The project was in immediate charge of D. W. Hamilton, and under the general supervision of L. F. Steiner, of the regular staff of the Vincennes Station.

The light-trap work was conducted in the same orchard with the bait trap experiments. One electrocutor trap was placed in each of 175 trees, in a block covering 5 1/2 acres, in addition to 15 traps hung over places where trees were missing in the outer rows. This area was in a part of the orchard which in the past has carried a very heavy codling moth population. Three types of lamps were used, the G-1, CX-60 watt inside frost, and 60-watt clear. They averaged respectively, 175, 96 and 83 moths per trap from May 31 to the end of the season. Traps over open spaces averaged only 8.8 moths each. The total catch for the area was approximately 22,000 moths, 44 percent of which were females.

In spite of the fact that the lights were not in operation until nearly the close of the spring-brood moth flight period, a definite reduction in worm population was obtained. The infestation records are given in the following table:

Infestation Records, Light-trap Experiments,
Troth Orchard, Orleans, Ind. - 1934

Variety	Light-trapped area		Unlighted area	
	Apples wormy	Worms per 100 apples	Apples wormy	Worms per 100 apples
	Percent		Percent	
Jonathan	17.2	22.1	31.0	50.1
Winesap	4.5	5.2	6.3	8.0
Rome	10.6	14.8	12.3	17.2
Average	10.8	14.0	16.5	25.1

Position of the traps was found to be very important in regulating their efficiency. Those 18 inches above the tree averaged but 45.2 moths per trap as compared to 136.5 for those lowered into the foliage. This comparison was made between June 10 and July 17 after which all traps were changed to the more effective position.

The light experiment was in the same orchard block as the bait-trap work, the two areas being about 10 tree rows apart. Adult movement was very extensive within the two trapped areas as well as between them. The portions of the orchard used as the check area undoubtedly had their populations of moths depleted as a result of movement into the trapped areas. The check area between the baited and lighted blocks was almost as clean as either of the treated areas.

Moth Behavior

At Orleans, advantage was taken of the opportunity offered by the maintenamce of bait traps in 35 acres and lights in 5 1/2 acres to obtain information on the migration habits of the moths. During the season a total of 1300 marked moths were released in and between the light and bait areas.

Those released between the two areas were five rows from the periphery of either area. Recovery from such releases was secured in both the light and bait blocks. It is quite probable that throughout the season the moth population was considerably reduced in this area by both the lights and baits. This is further substantiated by the fact that moths released in either of the areas were recovered in the other area.

When moths were released in the light and bait areas at the same time, the light traps recaptured the moths in that area much sooner than the baits recaptured those in their area, the largest percent being recovered the first and second nights after release as compared to five to eight days for the baits.

The following table shows the percent recovery and the distance moths traveled for each individual release.

Recovery of Marked Moths During the Season, Orleans, Ind. 1934

Period of release	No. Moths released	Where released	Percent recovery	Time out in days**	Mean Dist. traveled in feet	Longest Dist. trav. in feet
No. 1 6/13 -15	250	Baits	8.8	14	278	2079
No. 2 6/18 -20	100	Check	No recovery			
No. 3 7/24-8/10	100	Lights	17	3	53	248
No. 4 8/6 - 9	100	Baits	23	6	97	792
No. 5 8/7-10	100	Lights	27	1	84	363
No. 6 8/11-12	100	Check	1	4	380	380
No. 7 8/22-27	100	Baits	26	18	367	1370
No. 8* 8/23-25	100	Lights	42	6	58	726
No. 9 8/28-31	150	Check	8.7	14	357	941
No.10 *8/31-	100	Lights	38	6	101	1089
No.11 8/31	100	Baits	1	1	132	132

**Time out denotes number of days elapsed between the time the last moth was released and the time the last moth was recovered.

* While releases No. 10 and 8 were both the same color and made within a week of each other at the same place, only moths captured up until release 10 was made were credited to release No. 8.

Examinations of the light and bait traps at half-hourly intervals during the night indicated that the bait traps capture most of their moths at twilight and dawn, while the light traps do not become effective until the light intensity is less than two-tenths of one foot candle. Although moths were attracted to the light traps throughout the night, the greater percent of them were captured before 10:30 P.M.

6. Experiments in Codling Moth Control by the Use of Parasites

Natural enemies are often responsible for a marked reduction in numbers of various crop pests, and the object of these experiments was to determine the extent to which parasites can be relied upon to bring this about in the case of the codling moth. The egg parasite *Trichogramma minutum* Riley, which has been tested upon various other insects, was used for this purpose. The second phase of this activity was the colonization of *Ascogaster carpocapsea* Vier, a promising larval parasite, in various apple-producing sections of the United States where it previously did not occur. This latter is a repressive measure designed to aid in reducing the population so that the standard control program will be more effective.

Two experiments to test the effectiveness of *Trichogramma minutum* against the codling moth were conducted in 1934, one of these being at Cornelia, Georgia, and the other at Wenatchee, Washington. All *Trichogramma* used in these experiments were produced at the Pecan Insect Laboratory at Albany, Ga., in charge of Herbert Spencer.

Trichogramma Experiments at Cornelia, Ga.

This experiment was a repetition of that undertaken in 1933 in connection with the regular program of the Division of Fruit Insect Investigations, and was conducted in cooperation with the Georgia State Entomologist's Office. In the 1934 experiments, six plats, comprising 100 trees each were chosen, three of which received releases of *Trichogramma*, and three were used as controls. All plats received the standard spray treatment for that section, consisting of five to eight applications of lead arsenate to which Bordeaux mixture had been added. One unparasitized plat received only two applications, these being on May 14 and June 15. Release of *Trichogramma* ranged from 7500 to 33,750 per tree, these being liberated at intervals corresponding to the peaks of moth emergence of the various broods. The first releases were on June 4 to 16 and the last on September 10. A total of 1,885,000 parasites were liberated in the three colonization plats during the season.

Egg counts for the second, third, and fourth broods showed an average parasitization in three colonized plats of 2.1, 32.9, and 63.1 percent respectively; in the uncolonized plats 4.5, 16.3, and 71.1 percent. These counts showed no appreciable build-up in the parasite population which could be attributed to the liberations.

The records secured on fruit infestation do not reveal any appreciable reduction in the codling moth population as a result of the liberation of large numbers of *Trichogramma*.

It was noted that the increase of *Trichogramma* population was greatest in the most heavily infested plats, but that the infestations in these plats continued high throughout the season. The above experiments and observations in other orchards in northern Georgia indicate that the application of arsenical sprays does not materially reduce the *Trichogramma* population nor prevent its normal increase.

Trichogramma Experiments at Wenatchee, Wash.

The experimental plats comprised three colonization blocks of 100 trees each, with corresponding uncolonized plats in the same orchards. All of these received regular spray applications throughout the season, the material used being lead arsenate and fish oil only. In all, 3,550,000 parasites were liberated in three plats during the period from May 11 to August 30, the releases being timed to coincide with the peaks of codling moth emergence. Releases totaled approximately 12,000 per tree.

Native parasitization was almost negligible in all plats, the highest percentage recorded in any of the uncolonized plats being 1 percent. In the colonization plats a maximum parasitization of 15.4 percent was attained in one at the end of September. The average of the three colonized plats was 9.1 percent for August and September.

Counts of fallen and harvested fruit gave no indication of any degree of control resulting from the liberation of *Trichogramma*. When compared with the results of the Georgia experiment, they do support a conclusion previously reached by general observations, that this parasite is unable to attain a high percentage of parasitization where the host population is low. This is further supported by the finding in the Wenatchee and other sections of Washington, of

orchards poorly cared for and consequently with a high codling moth population, which showed a native *Trichogramma* parasitization of 75 to 80 percent. In both Washington and Georgia a high parasitization was always associated with a high host population.

Distribution of *Ascogaster carpocapsae* Vier.

This larval parasite normally destroys 25 to 40 percent of the codling moth larvae in the northeastern portion of the United States, but is rare or absent in other sections. It was introduced into the State of Washington in 1921-22, and quickly attained an average parasitization of approximately 30 percent. The purpose of the 1934 distribution program was to effect establishment of the parasite in all sections where it is not known to occur, with the hope that it will contribute to the reduction of the codling moth population and thus make possible a greater effectiveness of the spray program.

During 1934 a total of 39,400 *Ascogaster* in 30 shipments were distributed to the following 10 states:

Arkansas	Kansas
California	Mississippi
Colorado	Montana
Georgia	New Mexico
Idaho	Oregon

The parasites used in this colonization program were reared at the Oriental Fruit Moth Laboratory at Moorestown, N.J., under the direction of H. W. Allen, from a small stock originating from codling moth cocoons collected during the winter of 1933-34. Actual rearings were conducted on fruit moth larvae, as this host was more readily available and methods for mass rearing in the laboratory were already known. A total of 196,060 fruit moth eggs were secured for propagation purposes.

Adult parasites only were shipped and approximately 95 percent survived and were released in infested orchards. The results of these liberations will not be available until 1936, at which time collections of cocoons will be made to determine establishment and the percentage of parasitization attained.

The field colonization in the respective states was accomplished through cooperation with various State agencies. It is expected that the further distribution within the respective states will be made by these state organizations.

In addition to the material distributed during 1934, a total of 136,200 hosts were parasitized to provide an over-wintering stock. Approximately 25,000 adult parasites should emerge from this material and these will be available for distribution during the early summer of 1935.

7. Investigations on Grape Berry Moth

A small part of the Public Works Administration allotment was utilized in strengthening the work on the grape berry moth at the Bureau's grape insect station at Sandusky, Ohio. The control of this insect involves a serious spray residue problem, which apparently cannot be relieved in a practical way by washing the grapes at harvest time.

Tests of organic materials, mostly paralleling those conducted on apple and pear, were started in two vineyards in the northern Ohio grape belt. In one of the vineyards, however, the berry moth population turned out to be so light that infestation counts would have had no significance. Detailed counts were therefore not made, although much information was obtained on the effect of the materials on the fruit and foliage. In the other vineyard, the infestation was sufficiently severe to warrant completing the season.

In this vineyard, all plats were sprayed shortly after the blooming period for the control of diseases and insects, including the first brood of berry moth worms. The spray mixture used throughout in this application consisted of calcium arsenate, nicotine, and Bordeaux mixture, with fish oil and rosin fish-oil soap. The experimental materials were applied against the second brood of worms. The first experimental application was made on July 27; in most of the plats this was repeated on August 6 or 7.

The plats were replicated 5 times and the infestation records given in the following table represent the averages of the five replicates.

Field Experiments with Organic Materials in Control of Grape Berry Moth, Venice, Ohio - 1934

Plat No.	Material tested against second-brood berry moth[1]	Used with	Number of applications	Grapes wormy	Sugar content
				Percent	Brix test
1	None	-	-	15.5	19.8
2	Calcium arsenate, 2 1/2 lbs. in 100 gallons	Bordeaux, 2-4-50 Fish oil 1 pt.-100 gals.	1	6.7	18.7
3	Nicotine sulphate 1-800	White oil 1%	2	1.3	18.7
4	Derris powder (4% rotenone) 2-1/2-100	Fish oil 1 qt.-100 gallons	2	8.5	19.9
5	Processed nicotine-bentonite (8% nicotine) 3-100	Alone	2	5.3	19.4
6	Do. 3-100	White oil .5%	2	2.3	19.0
7	Do. 6-100	Do.	2	1.7	18.9
8	Processed nicotine-bentonite (8% nicotine) with copper 6-100	Do.	2	1.2	19.4
9	Nicotine tannate (liquid tannin, 3 pints, 50% free nicotine 1 pint, per 100 gallons)	Bentonite-sulphur 2 lbs. 100 gals.	1	5.2	17.2
10	Do.	Sulphonated castor oil, 1 qt.-100 gals.	1	4.1	19.1
11	Do.	Do.	2	2.9	19.3
12	Ground derris root 1 part, Kaolin 3 parts, containing 1% rotenone 10-100	White oil .5%	2	4.0	19.3
13	Ground pyrethrum 1 part, Kaolin 3 parts, containing .25% pyrethrins 10-100	Do.	2	1.8	19.0
14	Pyrethrum powder, .9% pyrethrins 2 1/2-100	Fish oil 1 qt.-100 gallons.	2	3.4	19.1
15	Phenothiazine 4 lbs. per 100 gallons.	Bentonite 4 lbs. fish oil 1 qt.-100 gals.	2	7.0	19.1

[1]All plats were sprayed against the first-brood with calcium arsenate, Bordeaux mixture, fish oil, and rosin fish-oil soap.

Although many of the materials gave satisfactory control of the grape berry moth, they all caused such a serious staining that the grapes were practically unsalable. Buyers and consumers now refuse to accept grapes showing a visible residue of any kind, even though it may be non-poisonous. The sprays containing oil destroyed the bloom on the grape berries, giving them a very unattractive appearance. It will be a difficult problem to find insecticides and carriers for insecticides that do not leave unsightly residues or otherwise mar the appearance of the fruit.

No foliage injury of any importance resulted from the treatments except in Plat 9, sprayed with nicotine tannate with bentonite-sulphur, where the foliage was considerably burned. This injury was reflected in the sugar content of the grapes, as indicated by the Brix test.

Cultural experiments for repression of the overwintering brood. -

Several vineyards were used for further experiments in cultural control, the cultivation during spring being such as to keep the overwintering cocoons of the berry moth as completely buried as possible until after the normal time of heaviest emergence of moths of the spring brood. In all of the vineyards so treated, first brood abundance was comparatively light, this condition varying with the degree of infestation the previous season, and local conditions which sometimes bring about concentrations of the moths in certain areas, usually along sheltered borders. In vineyards in which the berry moth infestation had been brought to a low point, either calcium arsenate or lead arsenate applied against the first brood of larvae resulted in almost complete control from a commercial standpoint. An increasing number of growers are attempting to bring about a decrease of moth population by attention to the manner of cultivating their vineyards during spring, and many favorable reports on the results obtained have been received.

Work has also been started with the burning of surface trash in the vineyard, as a means of reducing the population of hibernating berry moth larvae, which pass the winter in cocoons constructed in leaves on the ground. R. M. Merrill, of the Toledo Station of the Bureau of Agricultural Engineering, has cooperated in this work. With the experience gained from the construction of burners for the control of the corn borer, he has constructed a burner adapted for use in vineyards. Results of this work will not be available until another season.

8. Effect of Insecticides on Bees.

Experiments to determine the effect of a number of the organic insecticides on honey bees were conducted by G. E. Marvin under the direction of J. I. Hambleton, of the Bee Culture Laboratory at Somerset, Md. In a number of localities the sprays regularly used by orchardists have been found to have a detrimental effect on bees. In addition to the losses caused to honey producers, the reduction in the population of honey bees as well as of other pollinating insects often results in a reduced set of fruit in the orchard. It was therefore decided to try to obtain information on the effect on bees of the newer materials under experiment.

In a free choice test in the laboratory, nicotine sulphate and nicotine tannate were largely disregarded by the bees, indicating some repellant action.

Derris, cube and pyrethrum were extremely toxic under laboratory conditions both as stomach poisons and as contact sprays. Nicotine sulphate had no effect as a contact spray. When incorporated in a soap solution the same results were obtained as when soap alone was used, indicating that the soap was the active ingredient. Phenothiazine as a stomach poison had a slower action on the bees than lead arsenate, which in turn was not so rapid as derris, cube and pyrethrum. Insecticides containing nicotine had the least toxic effect on honey bees.

The field experiments with these materials were somewhat too limited to give conclusive results. The materials found repellent in the laboratory were apparently not repellent to bees after the spray had dried on the plants. Under the conditions of the field experiments nicotine sulphate and phenothiazine appeared to be toxic to the bees. The other five sprays - lead arsenate, nicotine bentonite, derris-kaolin, nicotine tannate and pyrethrum, in the amounts taken by the bees from the few flowers visited did not prove toxic within the period during which the field work was carried on, although they might have proved toxic if the bees had continued their visits to the sprayed flowers for a longer period.

9. Analysis of data.

The detailed statistical analysis of the data accumulated in the course of the experiments which is being made by K. W. Babcock, has not been completed. As indicated earlier in the report, however, this work has advanced to the point where it is evident that the worm population is so variable, even within a limited area in the same orchard, that rather wide differences must exist before conclusions can be drawn regarding the relative merits of the different materials. The statistical work included a study of the plans and methods used in the experiments and in sampling. This study when completed will be of great value in comparing the results obtained under different regional conditions and in providing more reliable and uniform methods for future work.

II. WORK CONDUCTED WITH FUNDS FROM AGRICULTURAL APPROPRIATION BILL

In order to present a complete picture of the work of the Fruit Insect Division on the codling moth-spray residue problem, a summary of the work carried on with regular funds is included herewith.

Yakima, Wash.

The Yakima station, E. J. Newcomer, in charge, is maintained in cooperation with the Insecticide Division, and with the Washington Agricultural Experiment Station.

Orchard Spraying Experiments.

The orchard spraying experiments during 1934 were planned (1) to determine the effect of various oils and other adhesives on the efficiency of cryolite; (2) to test calcium arsenate and zinc arsenite with buffers; (3) to test cuprous cyanide with mineral oil emulsion; and (4) to determine the relative effectiveness of various nicotine compounds. An orchard was used that was composed of Jonathan, Rome and Winesap apple trees. Each test was

replicated, in some cases five times, once on Jonathans, and twice each on Romes and Winesaps, and in most other cases four times, once each on Jonathans and Winesaps, and twice on Romes. The spraying was done with a stationary outfit using about 350 lbs. pressure. A calyx and 7 cover sprays were applied in all plats except 28, which had 12 cover sprays. The results of these experiments are given in the following table:

Field Experiments in Codling Moth Control
Yakima, Wash. - 1934

Plat No.	Treatment (Amounts given are for 100 gallons)	Worm injuries: Wormy fruit	Fruit free from worms and stings	Worms per 100 apples	Stings per 100 apples
		Percent	Percent		
2	Natural cryolite, 3 lbs.; 1/4% mineral oil	12.9	64.3	16.1	35.6
3	Do. ; 1/4% fish oil	15.3	59.5	19.8	39.6
4	Do. ; 1/8% fish oil	16.9	56.7	23.0	43.3
5	Do. ; 1/4% soap	14.7	55.7	17.0	47.0
6	Do. ; 1qt. colloidal spreader	12.1	62.7	14.7	37.2
7	Do. ; 1/8% soy bean oil	19.5	49.5	25.3	60.0
8	Do. ; no oil	30.0	44.3	44.1	79.1
30	Lead arsenate, 2 lbs.; 3/4% mineral oil	14.7	64.4	19.5	41.6
20[1]	Calcium arsenate, 3 lbs.; aluminum sulphate, 1/4 lb.; calcium hydrate, 1/4 lb.; 3/4% mineral oil in 1st to 4th cover sprays.	36.6	44.5	81.3	73.8
21[1]	Zinc arsenite, 3 lbs.; zinc sulphate, 1/4 lb; calcium hydrate, 1/4 lb. 3/4% mineral oil in 1st to 4th cover sprays.	59.1	14.0	118.2	137.4
30[1]	Lead arsenate, 2 lbs.; 3/4% mineral oil in all cover sprays.	23.6	54.8	33.5	48.5
23	Cuprous cyanide, 3 lbs.; 3/4% mineral oil in 2d, 3d, 5th, 6th and 7th cover sprays.	32.1	36.5	51.2	104.4
24	Nicotine sulphate, 1-1200; 3/4% mineral oil	27.8	53.2	37.1	32.9
25	Do. ; 1/4% mineral oil	46.0	40.2	78.8	48.9
26	Do. ; 1/4% fish oil	64.2	23.8	148.0	75.0
27	Nicotine bentonite (8% nicotine); 6 lbs.; 1/4% fish oil	30.4	54.7	40.3	24.6
28	Do. (except used every 7 to 10 days making a total of 13 applications)	18.7	69.7	24.6	18.7
29	Nicotine bentonite copper (8% nicotine) 6 lbs.	47.0	40.3	82.0	34.0
30	Lead arsenate, 2 lbs.; 3/4% #6 oil	14.7	64.4	19.5	41.6
31	Do. ; 3/4% #E 548 oil	17.3	59.5	24.1	49.0

[1] These results are from Romes only. All other results represent the average of replications on Jonathan, Rome, and Winesap.

No injury was noted except in Plat 28, where the rather excessive use of fish oil gave the trees a dull look and perhaps affected to some extent the size of the fruit. In the Rome trees sprayed with the #E548 oil, a slight russeting of foliage was noted in the center of the trees, but it was not severe enough to be of any consequence. No russeting was observed in the Jonathans or Winesaps.

A nicotine extract containing at least 8% nicotine alkaloid was tested extensively by C. H. Villmann, a grower near Yakima. He used it throughout the season on most of his orchard, putting on 10 or more applications at intervals of about 10 days. His schedule was very complicated in that he varied the quantity used and the materials added to the nicotine from time to time. Essentially, however, it consisted of the use of this extract at a strength practically equivalent to 40% nicotine sulphate at 1-1600, with oil emulsion or fish oil added to most of the applications. In order to determine the results obtained, samples of fruit from 10 Winesap trees scattered across a 20-acre block were examined. The percentage of wormy fruit on these varied from 9.6 to 29.2, with an average of 17.0. Two Rome trees in the wormiest part of the orchard were also examined and they averaged 49.0% wormy. Although no other treatments were available for comparison, the figures indicate that the control was not entirely satisfactory. It seems probable that the nicotine was used too weak, and that too small a quantity of oil was used with it for effective results.

Baiting Experiments

The chief objects of these experiments were to find a material or combination of materials that would be sufficiently attractive in trapping moths to warrant its cost, to find a suitable method of using such a material as a bait, and to study the reaction of the moths to such a bait. This work was started as a definite project in 1933, and several hundred materials and combinations have been tested. E. R. Van Leeuwen was in immediate charge of this work. Since a fermenting mixture of cane molasses and water has been extensively used in baiting work, and is quite attractive, it was arbitrarily employed as a standard with which to compare other materials or combinations. It was found that the addition of safrol, oil of mace, citral, bergamot oil, ammonia, limonene, or pine tar oil to the molasses bait increases the efficiency of the bait very materially.

Since pine tar oil is cheap and easily obtained, it appears to be the most practical of these materials, and it has therefore been studied more intensively than the others. When used with molasses in the proper amounts, it increases the number of moths captured by about 200 percent. For example, in one test, in which the baits were shifted each day for 21 days, in order to minimize the variation that occurs in individual trees, molasses alone attracted 688 moths and molasses plus pine tar oil attracted 1887 moths. This increase of about 200 percent would mean theoretically that since molasses alone attracts about 30 percent of the moths in an orchard, as shown by previous tests, molasses plus pine tar oil should attract 90 percent of the moths. Some tests to determine this point were made in 1934, but more extensive testing will be necessary to settle the question. However, a considerable increase in the number captured has already been shown. For example, in one test of a rather limited nature, 186 marked moths were released, and 133, or 71.5 percent, were recovered.

It was found also that a solution of molasses which was allowed to ferment and then kept in closed containers for some time appeared to give as good results as freshly prepared molasses bait. Mixtures of several chemicals are apparently more effective than any one of them used alone. It is thought that a dilute fermented molasses, to which has been added certain quantities of pine tar oil and ammonia may possibly be standardized in such a way that it can be used as a supplemental control measure. Further testing of this mixture will be necessary before any conclusions can be made.

Effect of Sprays on the Ascogaster parasite

An experiment was made to determine the effect of various spray materials on the percentage of parasitism by *Ascogaster carpocapsae*. It has been previously noted in the Yakima region and by other workers that although larvae are heavily parasitized in unsprayed orchards, the parasites are comparatively scarce in nearby orchards that have been sprayed.

The orchard used for this experiment had not been sprayed in 1933 and was very wormy, with approximately 45 percent of the hibernating larvae parasitized as determined by examining larvae from under bark early in the spring. The trees were all of the Jonathan variety. A calyx and six cover sprays were applied to each plat.

The percentage of parasitism was obtained by collecting the larvae from under burlap bands on all of the trees, and the percentage of wormy fruit determined by counting samples of fruit from four trees selected within each plat. Spray applications materially reduced the amount of parasitism and there seems to be a marked correlation between the percentage of wormy fruit and the percentage of parasitism. However, there is very little difference in the percentage of parasitism between the three spray treatments. Detailed figures are given in the following table.

Treatment	Percent apples wormy	Percent larvae parasitized
1. Cryolite and mineral oil	30.1	7.3
2. Cryolite alone	36.4	8.6
3. Nicotine sulfate and mineral oil	46.2	10.6
4. Unsprayed	94.4	26.6

Wenatchee, Wash.

The chief activities of the Wenatchee substation during the season of 1934 were experiments in the utilization of the egg parasite Trichogramma in the control of the codling moth (reported under the P.W.A. activities), and experiments with banding for codling moth control. M. A. Yothers was in immediate charge of this work. The banding experiments cannot be reported on until the bands have been examined during the winter.

Takoma Park, Md.

The work at the Takoma Park laboratory is in charge of E. H. Siegler, and is carried on in close cooperation with the chemists of the Insecticide

Division. The two major lines of investigation under way are laboratory insecticide tests of new materials preliminary to field testing, and investigations of chemically treated bands.

The laboratory project was strengthened during the winter of 1934 by a small grant of funds from the Tobacco Section of the Agricultural Adjustment Administration for special work with nicotine. During the remainder of the season the regular funds were supplemented by P.W.A. funds. The results of most of this laboratory work have been discussed in the section of this report devoted to P.W.A. activities. In addition, mention should be made of laboratory tests of stearic green which is an aceto-stearate of copper similar to Paris green. A paste of this material appears to have a high toxicity and satisfactory physical properties. There has not yet been opportunity to test it on foliage, nor in the control of the codling moth in the orchard.

In 1934 the results of banding tests conducted in 1933 were completed. The data included spring emergence of moths in 1934 as well as dead larvae and pupae, but did not take into account moth emergence during 1933, since it was not possible on account of lack of funds to make the necessary daily examinations during the active season. However, in view of the fact that moth emergence was taken in the spring of 1934, the comparative efficiency of the various treatments as reported may be considered fairly reliable. The results of the tests conducted have indicated that:

(1) - There appears to be no advantage in darkening a chemically treated band with lamp black in order to provide more attractive cocooning quarters than are furnished by the usual band. Apparently the standard treatment with beta naphthol and oil makes a sufficiently small, dark space suitable for the codling moth larva.

(2) - Two inch width half bands and 3 inch width half bands on the same trees were equally efficient with respect to the total catch of larvae.

(3) - In the case of the hot dip for bands, there is little to choose between paraffine base oils ranging from 77 to 300 viscosity S.U.V. and probably the naphthene base oils are as effective as the paraffine.

(4) - The cold dip is as effective as the hot.

During the 1934 season, tests were conducted to determine more exactly the weight of chemical coating needed in the bands for satisfactory effectiveness. Reports on this work are not yet available.

<u>Vincennes, Ind.</u>

The codling moth work of the Vincennes station is carried on jointly by the Fruit Insect Division, L. F. Steiner in charge, and the Insecticide Division, J. E. Fahey in charge, in cooperation with Purdue University.

<u>Field Experiments</u>

The field spraying control experiments were conducted by R. F. Sazama in the Huffman orchard at Bicknell, Ind., eighteen miles northeast of Vincennes.

This thirty-year-old orchard is about sixty acres in extent but there are only about 45 acres actually in trees. The Ben Davis block, used for the main experiments, consisted of three rows running across the entire width of the orchard at the southern end. The plats consisted of single trees replicated seven times and randomized throughout the whole block. Six trees were used in obtaining infestation records, while the seventh was used for furnishing samples for use by the chemist and also for artificial infestation in the laboratory.

Prior to the calyx spray three applications were made for the control of apple diseases. Intended primarily for codling moth control were the calyx spray and nine cover sprays, four of which were applied during the first brood.

The infestation in the orchard was very severe, and no supplementary measures were practiced. The crop in the experimental block was rather light. Most of the apples hung in clusters, and the trees were rather thick and bushy. Under these conditions, codling moth control by spraying was extremely difficult.

In addition to the experiments on Ben Davis reported in detail above, experiments were also conducted against the second and third broods of worms on the Winesap variety. The treatments given, the infestation counts, and the analyses for residue, are indicated in the following tables.

Results of Field Experiments in Codling Moth Control (Ben Davis Variety)
Bicknell, Ind - 1934

Plat No.	Treatment	Worm infestation: Wormy fruit	Worm infestation: Fruit free from worms and stings	Worm infestation: Worms per 100 apples	Worm infestation: Stings per 100 apples	Residue at Harvest[1]: Material	Residue at Harvest[1]: Grain per pound
		Percent	Percent				
1	Lead arsenate 1 1/2-50 with light Bordeaux in calyx and late covers; 2-50 in 1st brood covers.	56.8	1.3	124.4	474.3	Pb	.097
2	Lead arsenate 1 1/2-50 in calyx; 2-50 1st cover spray; natural cryolite 1 1/2-50 + 1/2% summer oil remainder of season.	75.0	5.6	148.3	147.1	Pb F	.010 .115
3	Lead arsenate 1 1/2-50 with Bordeaux in calyx; 2-50 with Bordeaux in 1st brood covers; nicotine sulphate 1-800 plus white oil 1% in 2nd & 3rd brood applications	60.4	4.1	153.6	226.7	Pb	.026
4	Cuprous cyanide 2-50 with white oil[2]	42.0	9.6	63.4	169.2	Cu	.279
5	Processed nicotine-bentonite (8% nicotine)2 1/2-50 with white oil emulsion[2] (calyx spray omitted)	81.4	4.4	153.5	121.7	Pb	.003
6	Same as Plat 5, except with calyx spray of lead arsenate	79.4	5.0	160.5	135.3	Pb	.007
7	Processed nicotine-bentonite 2 1/2-50 (8% nicotine) without oil	81.3	4.8	155.9	136.3	--	--
8	Processed nicotine-bentonite (8% nicotine) 1 1/4-50 with white oil emulsion[2]	86.4	4.0	171.0	123.5	--	--
9	Processed nicotine-bentonite (8% nicotine) 2 1/2-50, with raw white oil emulsified in tank	75.7	3.5	138.5	161.3	--	--
10	Lead arsenate 1 1/2-50 in calyx; 2-50 in 1st brood covers; cryolite (natural) 1 1/2-50 with white oil 1/2% rest of season	64.4	2.3	129.1	251.4	Pb	.030

[1] Residue analyses by Messrs. J. E. Fahey and H. W. Rusk of the Insecticide Division

[2] 1/4% in 1st cover; 1% in one 1st brood and one 2nd brood cover; 1/2% in all other cover sprays.

Results of Field Experiments in Codling Moth Control

(Winesap Variety)

Bicknell, Ind. - 1934

Plat No.	Treatment[1]	Worm injuries: Wormy fruit	Worm injuries: Fruit free from worms and stings	Worm injuries: Worms per 100 apples	Worm injuries: Stings per 100 apples	Residue at harvest: Material	Residue at harvest: Grain per pound
		Percent	Percent				
11	Lead arsenate 3-100 (with a weak Bordeaux mixture)	30.3	2.4	48.8	610.5	Pb	.122
12	White oil emulsion 1 1/2% to 2%, giving a total in 5 applications of 8.5% oil, plus oleic acid approximately .2%	37.9	6.5	58.0	322.9	Pb	.045
13	Processed nicotine-bentonite (8% nicotine) 5-100, without oil, applied at 10-day intervals	41.3	4.1	64.4	417.5	Pb	.034
14	Do. 5-100, with .5% white oil, emulsified in tank.	33.7	5.4	51.6	337.6	Pb	.031
15	Synthetic cryolite, 3-100, with white oil .5%	26.8	3.6	42.5	361.0	F	.041

[1] All plats received a calyx spray and four cover sprays of lead arsenate plus a light Bordeaux during the first brood period. The experimental treatments included five applications against worms of the 2nd and 3rd broods.

[2] Residue analyses by Messrs. J. E. Fahey and H. W. Rusk of the Insecticide Division.

Spray Injury: A spray program of a calyx and nine cover sprays of lead arsenate, even when buffered with a light Bordeaux, is severe treatment for apple trees in southern Indiana. From about the middle of the summer until after spraying was stopped, a gradually increasing amount of leaf yellowing and defoliation became evident on both the Ben Davis and the Winesap trees.

Although the natural cryolite in Plat 2 caused no foliage or fruit burning, it reduced the size of the fruit appreciably. Data are not at hand to show if this same dwarfing of the fruit occurred when the cryolite was confined to the sprays after the first brood period.

Oil-nicotine following lead arsenate left the foliage in excellent condition and fruit colored naturally.

Cuprous cyanide in the form used this year was eliminated from consideration as a spray material on Ben Davis. The fruit was so severely russetted that few, if any, apples could be considered first grade, even discounting insect injuries. The last two or three sprays also injured the foliage and by harvest time had caused a moderate amount of defoliation.

All the plots sprayed with nicotine-bentonite (5,6,7,8,9, 13 and 14) whether with or without oil, caused no injury to the fruit or the foliage.

On Winesap, the heavy dosages of mineral oil-oleic acid caused a moderate amount of blackening of the lenticels on the fruit, and a moderate amount of typical oil injury on the foliage. Since Winesap is considered resistant to oil injury, this spray program would be very hazardous on many other varieties such as Grimes, Jonathan, Ben Davis, or Red Delicious.

Spray Residue: It is evident that the cold washing solutions used commonly in this section are not adequate to cope with heavy deposits of lead since neither Plot 1 nor 11 could be brought below the required tolerance with either washing solution when used cold.

Likewise, with the cryolite-sprayed fruit, a reduction in the residue to meet the fluorine tolerance was not attained. Synthetic cryolite is apparently somewhat easier to remove than natural cryolite.

The lead residue was removed from all the apples subjected to a calyx and four cover sprays of lead arsenate and then followed by a non-lead program whether complicated by the presence of oil, or not.

The copper residue resulting from the use of cuprous cyanide in Plot 4 was not reduced appreciably by either washing solution.

Laboratory Experiments

More than 172,000 newly hatched larvae and 15,000 eggs have been used for testing materials in the laboratory this season. The studies in the laboratory included work with nicotine carried on in the late winter of 1934 with a small allotment of funds made by the Agricultural Adjustment Administration (Tobacco Section). As in the case at the Takoma Park station, the laboratory investigations during 1934 were in part financed with Public Works Administration funds. Certain of the results secured in the laboratory have been given in an earlier section of this report.

Apples were taken from the field experiments at Bicknell before and after certain of the sprays were applied, and exposed to artificial infestation in the laboratory. The results indicate a very low efficiency for all materials, but particularly for lead arsenate during the second half of the first brood period (no records for first half). They also show differences not apparent from the harvest records.

During the fore part of the second brood period, lead arsenate was exceeded only by oil-nicotine-bentonite, although cuprous cyanide-oil gave comparable results and the ovicidal value of oil-nicotine sulphate was not measured. During the two weeks after the last spray, oil-nicotine-bentonite and cuprous cyanide-oil again proved superior to lead arsenate.

Twenty-six laboratory larvicidal tests each comprising 10 or 15 spray treatments and requiring from 3000 to 9000 larvae were conducted during the season, the last test being completed in December. Distilled water was used in these tests and the quantities of soap or spreaders which gave the best results may differ from those needed in the field. Before adoption for field testing the better combinations will be retested using orchard waters.

Numerous materials were tested that proved of no value; these will not be listed here.

Lead arsenate was included in most tests as a standard of comparison. Where used alone at two pounds to 50 gallons its efficiency varied from 41.5 to 88.7 in different tests. The addition of soap in small quantities generally increased its efficiency, two ounces per pound of lead being superior to larger quantities. There appeared to be little difference between soaps. Oil added without lime caused severe flocculation and larvicidal efficiency was usually diminished. Soap and oil in combination increased its efficiency.

Zinc meta arsenite, supposedly more toxic than lead arsenate, failed to retain its superiority when combined with Bordeaux or zinc-sulphate lime used as buffers. When used alone in a field test, 50 percent defoliation resulted. When combined with 1-3-50 Bordeaux and oil it gave better control than when used alone. Soap also increased its effectiveness but these combinations were not tested on foliage.

Cuprous cyanide in combination with summer oil was very effective. The addition of soap to this combination increased control slightly. Certain buffer agents were tested but anything containing lime lowered its efficiency very much. The use of salt was suggested by Mr. Fahey with the idea that it would combine with free copper to help prevent russeting. It appeared to improve the material. Neither a raw oil nor soybean oil were as effective as the commercial summer oils when used with cuprous cyanide.

Cryolite was compared in both the synthetic and the natural form, the latter appearing somewhat more effective. Oil did not increase their efficiency in the laboratory.

Bait Trap Experiments

Bait Materials and Types of Traps - Approximately 20 bait combinations, six types of traps, and three methods of testing baits were compared using 600 traps. These traps captured about 23,500 moths during the season.

In the most extensive tests, oil of sassafras at one-half cc. per quart of 10 percent dark brown sugar solution proved superior to anything else, with citral and brown sugar in second place. These were used at Orleans in larger Public Works Administration tests, and the former also maintained its superiority there. In less extensive experiments with other aromatics the catch made by oil of sassafras was exceeded by that of bromo styrol in dark brown sugar. This appeared to be a very promising combination and was consistently best whereever used. Others showing promise were oil of mace, n butyl sulphide, citronellal and safrol, each in combination with 10 percent dark brown sugar.

Preliminary cooperative tests in which the better Vincennes baits were tested at Yakima and the better Yakima baits tested at Vincennes, indicated that the relative attractiveness of certain baits is entirely different in the two regions.

The standard quart glass jar with quarter mesh covers captured fewer moths than two-quart stew pans, glass cones and metal cones. However, it requires much less attention, less bait, and can be hung higher in the tree with less danger of spilling. A trap retaining these advantages, yet not having the objectionable features of the pans and cones except for original quantity of bait needed was devised. It consisted of two standard traps joined together in such a way that each could be emptied independently of the other but otherwise handled as a single unit. This proved 82 percent more efficient than the single jar and equalled the best of the other types in effectiveness. Two ages of the bait, or two different baits can be used thus insuring a more uniform protection for each tree in which it is used.

Other tests showed that three-mesh instead of four-mesh covers increased the efficiency 95 percent. If the baits are changed at two-week instead of three or four-week intervals, no covers need be used.

Bait Trap Efficiency.- The combinations of experimental baits maintained a rather low efficiency as indicated by percentage recovery after liberating nearly 1200 marked moths. Recoveries in baited areas varied from 9.3 to 40.8 percent. However, most of the traps were of the single quart type with four-mesh covers and they contained experimental baits many of which were of little value.

The average egg content before oviposition was approximately 325. The average egg content of 51 recaptured females alive at the time of dissection was 291. The least number of eggs found in a recaptured female was 120, eleven days after its release. It seems probable that no more than a third or possibly half of its potential output of eggs is deposited by the average female.

Adult Movement - Flights made by recaptured marked moths indicated that the average distance covered amounted to 180 feet or about six tree rows. The longest flight was between two points, 2,000 feet apart.

If this flight average of 180 feet is an indication of normal movement, it is evident that in experimental spray set-ups larger replicate plats must be used if any cumulative benefit from a treatment is expected to be carried through another brood and show up at harvest. It would appear that only a part of the benefit shown by a good spray treatment against one brood will be visible after another brood has been passed while movement away from the poor treatments will tend to make them appear better than they actually are.

Light Trap Experiments

Twelve light traps were operated from mid-June to September adjacent to some of the bait traps. Most of the moths captured were taken between June 20 and 30. During this period the traps captured 469 moths, 178 of which were females while the 12 nearest bait traps, two rows to the north, captured 203 moths, 123 of which were females. Both types of traps showed about the same fluctuations in moth abundance.

Lamps of higher intensities (200 watt) appear most attractive but those with some ultra violet output such as the G-1 and CX, even though of comparatively low wattage, were nearly as good. Traps hung over places where trees were missing caught practically no moths, indicating that the tree itself is the more powerful attrahent.

Banding Experiments

Tests with 400 bands at Parkersburg, Ill., conducted by A. J. Ackerman indicated that three-inch untreated corrugated paper, cold dipped beta-naphthol and alpha naphthylamine bands about equalled each other in attractiveness each type capturing from 4,500 to 4,800 larvae while hot dipped beta naphthol captured only 3,600. However, at Elberfeld the latter type proved much more attractive than untreated, indicating that variations in orchard or climatic conditions may affect the relative attractiveness of bands. All treated types were equally effective in preventing emergence. Four inch bands were but little better than two inch as regards numbers of larvae caught. The use of a two-inch band on both trunk and scaffold limbs resulted in the capture of 4,240 larvae on 50 trees as compared to 2,756 where the conventional single band (in this instance four inch) was used. Cost was very little more.

III. - COOPERATION IN RESIDUE REMOVAL INVESTIGATIONS

The Fruit Insect Division has cooperated actively with the Bureau of Plant Industry and with the Insecticide Division of this Bureau in experiments with spray residue removal. A number of plats were sprayed by the Yakima, Wash., station to furnish fruit treated with lead arsenate or cryolite in certain desired combinations according to a known schedule. Similarly, the Kearneysville station furnished to the Bureau of Plant Industry apples sprayed with lead arsenate, alone and also with several spreaders. This material came from a few extra trees not needed for the regular experimental plats.

Since the leadership in residue removal work rests with the Bureau of Plant Industry, a report on this work will be made by that agency.

(Not for Publication)

RESULTS OF CODLING MOTH INVESTIGATIONS 1934

Part III

Residue Removal Investigations

The following paper, entitled "Lead Residues and Their Removal as Influenced by Spray Programs," is included in this report for the information of those interested.

LEAD RESIDUES AND THEIR REMOVAL AS INFLUENCED BY SPRAY PROGRAMS [1]

By M. H. Haller, Bureau of Plant Industry, United States Department of Agriculture, J. H. Beaumont, University of Maryland, C. W. Murray and C. C. Cassil, Bureau of Entomology and Plant Quarantine, United States Department of Agriculture.

Introduction

With the establishment of a regulatory tolerance for lead in 1933 many fruit growers throughout the East turned to substitute sprays for lead arsenate or to restricted spray programs. These efforts to avoid washing usually resulted in increased worm infestation and were found by experience to be uneconomic. This has caused a return to a more adequate program of lead arsenate sprays and the necessity of washing to remove the excessive residue. Since the growers are now to a large extent equipped to wash their fruit, it should be possible to follow more effective spray programs than are usually recommended.

The investigations reported here were undertaken in 1934 to determine to what extent certain modifications of the spray program that might increase its effectiveness would influence the amount of residue on the fruit at harvest or the difficulty of removal.

Material and Methods

The fruit for these investigations was grown near Frederick, Md., and Kearneysville, W. Va.[2] At Frederick, Md. four varieties of apples (Jonathan, Grimes Golden, Delicious and Stayman Winesap) were given

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1/ Presented at the meeting of the American Society for Horticultural Science, Pittsburgh, Pa., December 27-29, 1934; to be published in the Proceedings of the Society.

2/ The cooperation of Mr. E. Gould and his associates of the U. S. Bureau of Entomology and Plant Quarantine, who were responsible for the spray plots at Kearneysville, is gratefully acknowledged.

differential spray treatments consisting of five and seven cover sprays of lead arsenate, 3 pounds to 100 gallons. To certain of the five cover sprayplots fish oil (1 qt. to 100 gal.) or mineral-oil emulsion (1 gal. to 100 gal.) was added in early and late cover sprays. Because of the use of oil in some of the early cover sprays Bordeaux mixture was used as the fungicide during the entire season. At Kearneysville, W. Va., two varieties of apples (Stayman Winesap and York Imperial) were sprayed with five and seven cover sprays of lead arsenate 3 pounds to 100 gallons with fish oil (1 qt. to 100 gal.), mineral oil emulsion (1 gal. to 100 gal.) or casein-lime spreader (1 lb. to 100 gal.) added to the second brood cover sprays (fourth and subsequent sprays). The usual fungicides were added to these sprays.

To reduce the sampling variability, the apples were sorted and only the medium-sized fruit was used. The fruit was held at 32° F. until the washing treatments could be given which was usually within a week of picking. For the washing treatments a flotation-type washer having a false floor and a slat conveyor that pushed the fruit through the solution was used. The time of exposure to the wash solution was one minute.

Samples for analysis usually consisted of 60 to 90 apples for unwashed lots, and of 30 to 50 apples for washed lots. Analyses were made in duplicate or triplicate, 15 to 30 apples being used for each analysis. Since the ratio of lead to arsenic trioxide in the residues from lead arsenate sprays is almost invariably in excess of 2 to 1 while the ratio of their tolerances is less than 2 to 1 any treatment that effectively removes the lead can be assumed to be effective for arsenic. For this reason lead only was determined. The consequent saving in time permitted of more extensive removal investigations than would have been possible if both lead and arsenic had been determined.

The method used for determining the lead in these samples may be very briefly described as follows: 3/ The peels from each sample of 15 to 30 apples were heated with concentrated nitric acid until they were completely "mushed" and showed little or no stringiness. The mush was then made to volume and filtered, after which a suitable portion of the filtrate was made ammoniacal and extracted with a chloroform solution of diphenyl thiocarbazone. The chloroform solution, which contained the lead, was evaporated to dryness and heated with a little concentrated nitric acid to destroy the organic lead compound, after which the solution was diluted and electrolyzed between platinum electrodes. The deposit of lead peroxide was dissolved from the anode by means of a solution containing potassium iodide, and the liberated iodine titrated with standard thiosulphate solution.

3/ This is a modification of the method described by Wichmann, Murray, Harris, Clifford, Loughrey and Vorhes, Journal of the Association of Official Agricultural Chemists 17 (1): 108-135, 1934.

Table 1. Relation of spray treatments to lead residues to harvest and after various washing treatments. All results in grains of lead per pound of fruit.

Spray treatments	Washing treatments			
	Not washed	0.5%HCl Rm. temp.	1.5% HCl Rm. temp.	1.5%HCl 100°F.
	Jonathan (Frederick, Md.)			
5 covers L.A.1/	.049	.013		
5 " " Plus F.O.2/ in 1 & 2	.036	.012		
5 " " " " " 1,2,4 & 5	.052	.012	.008	
5 " " " M.O.3/ " 1 & 2	.044	.014		
5 " " " " " 4 & 5	.086	.025	.016	.016
5 " " " " " 1,2,4 & 5	.084	.024	.017	.015
7 " "	.066	.018		
	Grimes Golden (Frederick, Md.)			
5 Covers L.A.	.069	.018		
5 " " plus F.O. in 1 & 2	.061	.016		
5 " " " " " 1,2,4,&5	.071	.015	.012	
5 " " " M.O. " 1 & 2	.057	.018		
5 " " " " " 4 & 5	.089	.026	.016	.014
5 " " " " " 1,2,4, &5	.086	.026	.018	.013
7 " "	.060	.014		
	Stayman Winesap(Kearneysville, W.Va.)			
5 " "	.058	.024	.017	
5 " " plus C.C.S.4/ in 4 & 5	.070	.025		
5 " " " F.O. " 4 & 5	.070	.026	.014	.012
5 " " " M.O. " 4 & 5	.077	.032	.020	.014
7 " "	.103	.036	.020	.016
7 " " " C.C.S. " 4 - 7	.122	.034	.019	.016
7 " " " F.O. " 4 - 7	.128	.043	.021	.015
7 " " " M.O. " 4 - 7	.137	.052	.029	.026
	York Imperial (Kearneysville, W.Va.)			
5 " "	.056	.023	.016	
5 " " plus C.C.S. in 4 & 5	.066	.023		
5 " " " F.O. " 4 & 5	.075	.024	.018	.012
5 " " " M.O. " 4 & 5	.092	.038	.027	.018
7 " "	.115	.046	.020	.014
7 " " " C.C.S. In 4 - 7	.108	.030	.017	.014
7 " " " F.O. " 4 - 7	.115	.034	.017	.014
7 " " " M.O. " 4 - 7	.168	.052	.035	.030

Note 1/ L.A. = Lead Arsenate 3 lb. to 100 gal.
2/ F.O. = Fish oil 1 qt. to 100 gal.
3/ M.O. = Mineral oil emulsion 1 gal. to 100 gal.
4/ C.C.S.= Calcium caseinate spreader, 1 lb. to 100 gal.

Results

The lead residues at harvest and after certain washing treatments are presented in table 1 for Jonathan and Grimes Golden from Frederick, Md., and for Stayman Winesap and York Imperial from Kearneysville, W. Va. The plots with five cover sprays of lead arsenate plus a fungicide correspond closely to common commercial practice in the East and are used as standards for comparison with the other plots. The results show that the addition of either fish oil or mineral oil to the first two cover sprays (table 1) has not increased the amount of residue at harvest or increased the difficulty of removal

Although the results for Jonathan indicate a lower residue at harvest with the addition of fish oil in the first two covers the other varieties from Frederick, Md., do not show any such reduction in residue.

The addition of fish oil to the second brood cover sprays usually increased the amount of residue at harvest but did not make removal more difficult with the fruit from either Frederick, Md., or Kearneysville, W. Va. Likewise the addition of calcium caseinate spreader to the second brood sprays at Kearneysville usually increased the load at harvest but did not increase the difficulty of removal.

The addition of mineral oil to the second brood cover sprays in all cases greatly increased the amount of residue at harvest and also made cleaning considerably more difficult.

The washing treatment required to condition the fruit varied with the spray treatment, variety and locality where grown. When washed with 0.5 percent hydrochloric acid at room temperature, the residues on all lots of Jonathan and Grimes Golden from Frederick, Md., were brought to below the lead tolerance of .019 grain lead per pound of fruit except on the apples from the plots that had mineral oil in the late cover sprays. This same washing treatment was ineffective with either Stayman Winesap or York Imperial from any of the spray plots at Kearneysville. When the acid concentration of the washing solution was increased to 1.5 percent at room temperature the Jonathan and Grimes Golden apples from the plots with late cover sprays of lead arsenate and mineral oil were cleaned to within the tolerance. This treatment, was, however, ineffective with apples from comparably sprayed Stayman Winesap and York Imperial plots at Kearneysville, W. Va., or with apples from any of the seven cover spray plots at Kearneysville, but was effective with the apples from the five cover plots other than those receiving sprays containing mineral oil. With 1.5 percent hydrochloric acid heated to 100° F., the apples from all the Stayman Winesap and York Imperial plots except those receiving seven cover sprays, the last four containing mineral oil, were cleaned to within the tolerance. It might be mentioned in this connection that with the addition of Vatsol to the above washing solution the apples from these plots also were brought to within the tolerance. (Results not given.)

The amount of residue at harvest and consequently the ease of cleaning following a given spray program may vary considerably depending on the

weather conditions prevailing during the growing season. The season of 1934 was abnormal in that the early part of the season was unusually dry and in the latter part, particularly September, the rainfall greatly exceeded normal. A comparison of the 1934 results with those of 1933 indicates that with similar spray schedules of lead arsenate the residues at harvest were about the same both seasons but that their removal was considerably more difficult in 1934. Thus, all of our experimental lots in 1933 that received five cover sprays of lead arsenate were cleaned to less than .01 grain of lead per pound by washing with 0.5 percent hydrochloric acid at room temperature, whereas with the same washing treatment in 1934 the residue on similarly sprayed fruit was in all cases above .01 grain per pound and was even in excess of the tolerance on the apples from Kearneysville. This indicates that with hydrochloric acid at room temperature more effective cleaning than that obtained in 1934 might normally be expected.

Discussion

The results of spraying and washing investigations in the Shenandoah-Cumberland Valley in 1934 indicate that fish oil or mineral oil might be added to the first two lead arsenate cover sprays without influencing the amount of residue at harvest or its removal. It should be pointed out that if mineral oil is used a sulfur fungicide cannot be, and if Bordeaux is used as the fungicide there may be danger of spray burn during cool weather.

The results indicate that the addition of mineral oil, fish oil or casein-lime spreader to the late cover sprays of lead arsenate increases the residue at harvest, particularly so in the case of mineral oil. The difficulty of removing the excessive residue was greatly increased by the addition of mineral oil to the late cover sprays but was not appreciably influenced by the addition of fish oil and casein-lime spreader.

The application of seven cover sprays extending later in the season increased the amount of residue at harvest and the difficulty of removal as compared with that following five cover sprays.

(Not for Publication)

RESULTS OF CODLING MOTH INVESTIGATIONS, 1934.

Part IV.

General Summary and Discussion.

I. Seasonal conditions and codling moth abundance during the 1934 season.

In the Northwest the season started two weeks or more earlier than normal, and a month earlier than in 1933, permitting in many localities the development of a large third brood of worms with consequent serious damage late in the season. In other localities, particularly in certain parts of Oregon, there was sufficient cool weather in the early season so that the infestations were practically normal in spite of the long season. In the Middle West the season started a little earlier than usual. From the beginning temperatures were high, and as a result the worms of the first brood were extremely numerous. With the unprecedented heat and drought of midsummer, however, worms of the second brood were abnormally scarce, apparently because of the effect of these conditions on the egg-laying activities of the moths or upon the eggs themselves after they were laid. In certain localities worms again became numerous in late summer and early fall after temperatures became lower. In the East, conditions appeared to be approximately normal, although in the northeastern part of the United States, especially in New York State, the extremely low temperatures of the preceding winter had reduced materially the carry-over.

II. Results of experimental work.

A. Control by insecticides.

(1) Lead arsenate - Lead arsenate continued to be the standard insecticide for codling moth control, although it is admittedly inadequate to deal with severe infestations. Reports from Arkansas, Indiana, Virginia, and New Jersey mention more or less foliage injury from its use. The addition of white oil atstrengths varying from 1/2 percent to 1 percent has in practically all cases increased the control obtained and at the same time has caused serious difficulty in residue removal, necessitating the use of the best equipment, the heating of the solutions, and the addition of wetting agents.

(2) Non-lead arsenicals.

Calcium arsenate - Much less work was done with calcium arsenate during 1934 than in the preceding year. In general the results in 1934 were unsatisfactory - similar to those obtained in 1933. In a few States, however, - Iowa, Oregon, and Washington - favorable results have been obtained. It appears that calcium arsenate has the greatest chance of success in areas in which the codling moth is a minor factor, such as the Willamette Valley in Oregon, upper Michigan, the Hudson Valley, and the

New England States. In areas in which infestations are severe, good results have been the exception rather than the rule.

Manganese arsenate - Tests reported from California, Delaware, Ohio, and Oregon indicated that manganese arsenate is decidedly inferior to lead arsenate in its effectiveness. In California it caused severe injury. In Iowa, under conditions of light infestation, it was apparently about equal to lead arsenate.

Magnesium arsenate - A single test was reported from Delaware, in which the performance of this material was very poor.

Zinc arsenate - In Michigan a form of zinc arsenate has appeared to be nearly as effective as lead arsenate, confirming results obtained in 1933. Missouri and Illinois also reported results comparable with those from the use of lead arsenate. On the other hand, the performance of certain forms of zinc arsenate in Delaware and Indiana was very unsatisfactory.

Zinc arsenite - Zinc arsenite was tested by State workers in Idaho and Oregon. In both series of experiments the control was comparable to that resulting from the use of lead arsenate. Zinc sulphate and aluminum sulphate were used as buffers to prevent foliage injury. Such combinations have not been tested extensively under humid conditions; without the buffers, zinc arsenite often causes very serious foliage injury. Zinc arsenite combined with zinc sulphate and calcium hydroxide gave poor results in experiments conducted at the Yakima station of the Bureau of Entomology and Plant Quarantine.

Stearic green - Stearic green, a compound similar to Paris green, in a paste form showed good toxicity in laboratory experiments conducted by the Bureau of Entomology and Plant Quarantine but has not as yet been tested in the field or on foliage.

(3) Fluorine compounds.

Cryolite - In Colorado and Washington, cryolite has continued to give effective control of the codling moth. In Oregon and California, however, the results have been much less satisfactory. In the Middle West and East results continue to be rather conflicting, a few stations reporting fair to satisfactory control when the materials were used with oil during the latter part of the season. When used without oil the results have been invariably poor. The removal of cryolite in the Northwest has proved to be an extremely difficult matter. Residues resulting from schedules including more than two late-brood applications of cryolite have in many cases not been cleaned to the tolerance. In general, synthetic cryolite has been found a little less effective than the natural cryolite.

Barium fluosilicate - This material was tested at comparatively few points in 1934. In Oregon and Indiana it gave poor control.

In California it gave fair control, but some defoliation.

(4) <u>Other inorganic materials</u>.

<u>Cuprous cyanide</u> - In 5 tests out of 7, cuprous cyanide has given effective control. In 3 of these tests, however, it caused serious injury, particularly in the form of fruit russetting.

(5) <u>Organic materials</u>.

<u>Oil-nicotine</u> - When applied on the same schedule as lead arsenate, the combination of oil with nicotine sulphate has given equivalent results in a number of experiments and somewhat poorer control in a few. When the number of applications has been increased to the point where the sprays are applied every week to ten days, the oil-nicotine mixture has in many cases given better results than those obtained by the use of lead arsenate. Mention should be made, however, of certain disadvantages. An entire-season schedule of applications of nicotine and oil has in some cases resulted in direct injury and stunting of the foliage and fruit. The oil is incompatible with sulphur fungicides. The use of oil-nicotine in part of the schedule, following lead arsenate, interferes seriously with the removal of lead and arsenic residues, even though the total quantity of residue involved is less than that deposited by a full-season schedule of lead arsenate without oil in the late sprays.

The oil-nicotine combination may possibly find a place in the spraying of early varieties, such as the Transparent, which is often badly bruised in the washing process, and which requires only a small number of first-brood spray applications. It may also find a place in sections in which the residues are moderate, as a means of avoiding the necessity for washing.

<u>Nicotine tannate</u> - Nicotine tannate has continued to give effective control in experiments conducted in New Jersey. The Bureau of Entomology and Plant Quarantine tested this mixture at a number of points during the season of 1934. In general the results have been much inferior to those obtained with lead arsenate and with the nicotine-oil mixture. When used with bentonite-sulphur the control obtained has been somewhat better, but the sulphur has caused severe fruit injury in several of the experiments and appears unsuitable for use in midsummer under conditions of high temperature.

<u>Nicotine-bentonite</u> - A factory processed material was used extensively in the work conducted by the Bureau of Entomology and Plant Quarantine. The results were in general very unsatisfactory. Apparently the wetting agent used in preparing this nicotine-bentonite mixture caused too much of a run-off of the material, resulting in a very light deposit. The New Jersey station has reported favorable results with a mixture of

nicotine and bentonite prepared in the spray tank, and this combination is undoubtedly worth further investigation. Several workers have commented on the heavy deposit of spray residue resulting from the frequent application of mixtures containing bentonite. Although the bentonite is nonpoisonous to human beings, buyers discriminate against fruit showing any signs of visible residue.

Derris - Derris was tested very extensively by the Bureau of Entomology and Plant Quarantine during the 1934 season. The mixture used consisted of one part of finely ground derris root with three parts of kaolin, the specifications calling for 1 percent of rotenone in the finished product. This material was tested at strengths of 5 pounds and 10 pounds per 100 gallons, respectively, on varying schedules and in some cases in combination with oil. The results throughout were definitely unsatisfactory. Neither increases in concentration nor increases in the number of applications resulted in increased control, indicating that the material had little or no value. The addition of oil gave it a certain degree of effectiveness, but this is attributed to the oil rather than to the derris. The kaolin used as a carrier resulted in an unsightly deposit that could not be removed by any of the standard washing treatments, and otherwise high quality fruit from certain of the experimental blocks had to be disposed of at a cannery. The Oregon station tested derris in the Willamette Valley with very poor results.

Cubé - Mixtures of cubé root, similar to the mixtures of derris root just mentioned, were tested on a limited scale in certain of the Bureau's experiments. The results indicated that such mixtures of cubé root are ineffective in controlling the codling moth.

Pyrethrum - Ground pyrethrum diluted with kaolin to contain 0.25 percent of pyrethrins was tested by the Bureau of Entomology and Plant Quarantine at a number of points. The results were no better than those obtained with derris and cubé mixtures. Pyrethrum was used in a number of different forms by the Washington Experiment Station at strengths costing approximately the same as nicotine sulphate. The codling moth control was unsatisfactory in every case.

B. Control by means other than spraying.

(1) Bands

The use of chemically treated bands appears to be increasing. There is still a definite need for standardization of their manufacture. In Delaware the tendency has been toward the use of untreated bands, which involve a low cash outlay. Practical tests in Illinois showed a reduction in the amount of codling moth injury from 30 percent in the unbanded portion of the orchard to 17 percent in the banded portion. A three-year

experiment in the Willamette Valley showed the banded portion of the orchard to be 98 percent clean and the unbanded 94 percent. In work conducted by the Bureau of Entomology and Plant Quarantine in southern Indiana reductions of 36 to 48 percent in the worm population resulted from the cleaning and banding of half of a 40-acre orchard.

(2) Sanitation.

Numerous further observations have been added to previous information on the value of orchard and packing shed sanitation. In Indiana, burning over the surface of the orchar with an oil burner apparently reduced the codling moth population 17 percent. The Indiana station has also developed a mixture for closing knot holes and other places which are not readily reached in the scraping and cleaning operations.

(3) Bait trap studies.

In an experiment in southern Indiana involving the baiting of a 35-acre block in a large orchard the Bureau of Entomology and Plant Quarantine has demonstrated a reduction of infestation; otherwise the baits are being used chiefly as a means for timing spray applications.

(4) Light traps.

The work conducted jointly by the Bureau of Entomology and Plant Quarantine and the New York Experiment Station has continued to demonstrate that the use of the electrocutor type of light traps gives a definite reduction in codling moth infestation. Similar results have been obtained by the Bureau of Entomology and Plant Quarantine in a 5-1/2-acre block in southern Indiana. A slight benefit resulted from the use of light traps in certain experiments carried on by the Massachusetts station. On the other hand, the installation of 30 light traps in an orchard in Michigan showed no improvement.

(5) Parasite control.

The results of *Trichogramma* experiments reported during 1934 were entirely negative.